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SURGICAL APPLICATIONS OF THERAPEUTIC VENOUS OBSTRUCTION *

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It is remarkable that a process so apparent as the circulation of the blood could have remained undiscovered through so many centuries during which there was an accumulation of knowledge of other more complex phenomena. If one only contemplates the vast number of opportunities which were presented for the discovery of the circulation of the blood and recalls the simplicity of the experiments of William Harvey, one is amazed that this discovery should have been deferred so long. It would seem as if a sort of mysticism always assigned to the cardiovascular mechanism had prevented an appreciation of its simple realities. Discussions of the problems of the circulation of the extremities still contain many vague ideas and few definite terms. It would seem worth while, therefore, to discuss some therapeutic measure applicable to disease of the circulation of the extremities with the object in view of tracing its historical development and collecting the existent definite knowledge concerning its fundamental principles.

Therapeutic venous obstruction is as old as medical literature. It is quite natural that intentional obliteration of veins should have been first used in the treatment of conditions in which there were external manifestations of disease in the veins. Hippocrates [1] described a method of obliteration of a varix in which needles were passed into the dilated veins. Paul of Aegina,[2] Celsus and Galen described methods of excision of varicose veins, and this operation is said to have been mentioned by Pliny and Plutarchus. The fact that the celebrated Caius Marius submitted to an operation for varicose veins without being bound is mentioned as an evidence of his fortitude. In more recent times, Max Schede [3] and Trendelenburg [4] revived the operative treat-

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* From the Department of Surgery, Vanderbilt University Medical School.

* The Hodgen Lecture of the St. Louis Surgical Society, delivered in St. Louis, Jan. 15, 1929.

1. Works of Hippocrates, translated by Francis Adams, New York, William Wood & Company, vol. 2, p. 305.

2. Paulus Aegeneta: New Sydenham Series, 1846, vol. 2, p. 406.

3. Schede, Max: Berl. klin. Wchnschr. **14**:85, 1877.

4. Trendelenburg: Beitr. z. klin. Chir. **7**:195, 1891.

ment for varicose veins. During the past few years, there has been a marked revival of interest in therapeutic venous occlusion by injection. It is interesting to note that this method was extensively used and discarded previous to the development of antiseptic surgery.

The origination of the idea of purposeful occlusion of normal veins as a therapeutic measure in the treatment for arterial disease is usually ascribed to Sir George Makins [5] who observed, from experiences in the South African War, that there was a smaller incidence of gangrene in those instances of arteriovenous fistula resulting from gunshot wounds which were treated by ligation of both the artery and the vein than in similar wounds treated by ligation of the artery alone. It is interesting to note, however, that this observation of Makins was not recorded until his delivery of the Bradshaw Lecture in 1913, and that at this time he referred only to a study of a series of records of arteriovenous fistula.

In a subsequent address, the Hunterian Oration delivered in February, 1917, Makins [6] went further in his conclusions as to the application of venous occlusion as a therapeutic measure. In this address he advocated the possible value of ligature of the vein as a therapeutic measure in instances in which there is arterial occlusion but no fistulous opening between the artery and the vein. It is interesting, however, to note that in this address, Makins referred to the observations of von Oppel concerning the beneficial effects of simple ligation of the vein in instances of spontaneous arterial occlusion without arteriovenous fistula.

During the World War, this subject was made the principal point of discussion at a meeting of the French Surgical Society in July, 1917, at which time Professor Tuffier [7] expressed his views on the subject in the following words: [8]

> We all know that the three arterial ligations which most often expose patients to grave dangers of disturbance are (1) those of the femoral trunk, (2) those of the carotid at its bifurcation, and (3) those of the popliteal artery in the lower half of the popliteal space. If I believe everything that I have seen of ligation since the beginning of this war, it is that the occlusion of the popliteal in its lower half causes most disasters; gangrene of the limb is very often a consequence of it.
>
> To lessen the chances of ischaemia or of the gangrene following ligatures in these regions, it has been advised to have recourse more often to lateral sutures in all cases where the nature of the lesions permitted it, and I fully share this opinion. There is a great advantage in having recourse to arterial sutures; they are less difficult to place than one believes.

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5. Makins: Gunshot Wounds of the Blood Vessels, New York, William Wood & Company, 1919, p. 101.
6. Makins: Lancet **1**:249, 1917.
7. Tuffier: Bull. et mém. Soc. de chir. de Paris **43**:1469, 1917.
8. Halsted's translation.

There is a practice to which I desire again to direct your attention in this connection; it is ligation of the corresponding healthy vein in all cases of ligation of the great vessels of the root of the limbs. This question, raised long ago, can find in actual occurrences some particularly suggestive statistics. There is first a fact which appears well demonstrated; it is that ligation of the vein and of the artery in the case of wounds of the two vessels does not increase the danger of ischaemia. Moreover, the statistics of the English Army, which Sir George Makins has communicated to us, give in this connection the following ratios: Ligation of the artery alone is followed in a general way by gangrene in 40.2 per cent, whereas simultaneous ligation of the artery and of the vein under the same conditions gives 24.5 per cent; and I speak only of gangrene from ischaemia.

The most marked difference is in connection with the popliteal; ligation of the artery alone in twenty-four cases gave favorable results in 58.33 per cent, and gangrene in 41.66 per cent. Simultaneous ligation of the artery and of the vein has given in twenty-eight cases twenty-two favorable results and only six cases of gangrene.

It is interesting to note that Tuffier referred to simultaneous ligation of the vein as "a subject raised long ago." The danger of ligature of veins in the presence of suppuration was emphasized by Pirogoff. After the development of antiseptic surgery, both experimental and clinical observations were reported which justified the conclusion that ligature of the vein with the artery does not entail a risk of gangrene greater than ligature of the artery alone. I have found no record previous to the beginning of the twentieth century which contained a definite statement indicating that ligation of a vein is a therapeutic measure in the treatment of arterial disease. In a private communication, Makins stated: "At the time of the Boer War (1899-1902), I held the generally accepted view of the necessity of sparing the vein."

In a report of a study of the surgical treatment for aneurysm of the subclavian artery, Halsted [9] discussed the subject of therapeutic occlusion of healthy veins at some length. In this publication, he called attention to the fact that occlusion of the vein, as a method of prevention of gangrene, had been recommended previous to the time of the publications of Makins. He expressed the belief that the first record of the idea is contained in a report of an operation by von Oppel,[10] published in 1908. It is interesting to note that this publication of von Oppel dealt with an operation on a patient suffering from arteriovenous fistula.

It would seem, therefore, that the fundamental principles involved in therapeutic venous obstruction had been considered the same whether this operation was applied to arteriovenous fistula or to arterial obstruction without arteriovenous communication.

I believe that this opinion is erroneous and that careful study of the conditions present in varicose veins, arteriovenous fistula, and in arterial

9. Halsted: Johns Hopkins Hosp. Rep. **21**:1, 1921.

10. Von Oppel: Arch. f. klin. Chir. **86**:31, 1908.

obstruction without fistula will show that the fundamental principles involved in the application of therapeutic venous obstruction to these different conditions are not the same.

In order to make myself clear in the attempt to analyze the different conditions in the circulation of the extremities for which therapeutic venous occlusion is indicated, it will be necessary to review briefly some of the most elemental factors concerned in the circulation of blood.

In the beginning, it is worth while to point out that however complex the function of the circulation of the blood in health or the pathologic changes in blood flow in disease may be, the actual circulation of blood is only a fluid flowing through tubes. The physical and chemical characteristics of the fluid may vary and the mechanism of control of the cross-section area of the tubes may be exceedingly complex, but the fact remains that in the last analysis the circulation of the blood is a simple mechanical phenomenon.

If the circulation of the blood in health or disease is approached from this point of view, it is at once apparent that with the assumption of a constancy of the physical and chemical properties of the blood, there are two important variable factors: (1) the amount of blood which passes through a unit volume of tissue in a given time, the volume flow, and (2) the tension of the blood in the vessels through which it is passing, the intravascular pressure. It might be said that if the peripheral circulation is to be discussed from the point of view of its being a mere mechanical phenomena of a fluid flowing through tubes, volume flow was the single important factor since it is obvious that the amount of fluid which flows through a unit length of a tube is dependent on the cross-section diameter of this tube and the difference in pressures between the inflowing and outflowing points, but certain evidence exists which makes it seem likely that nutrition of the tissues is dependent on the conditions of intravascular pressure independent of volume flow. It is also worth while to emphasize another point, the lack of appreciation of which has often led to error. The volume flow of blood must, of necessity, in all instances be the summation of all the blood flowing through every channel of that particular portion of the body under consideration. For example, the cardiac output or the total amount of blood which is put out by the heart in a unit of time must be the same as that which is flowing through every capillary in the body. It is possible to have great variations in the volume flow of blood through any particular organ without necessarily changing the cardiac output or total volume flow. For example, during the process of digestion, there may be a much larger amount of blood flowing through the intra-abdominal organs and a correspondingly less amount of blood flowing through the peripheral structures. This principle is perhaps best referred to as the distribution of blood flow. The amount of blood flowing

through an extremity may be actually greater than normal, in spite of the fact that a portion of this extremity may be receiving a blood flow below that necessary for normal nutrition. I wish particularly to emphasize this point because of conclusions that are now being drawn from certain experimental work in which it is assumed that evidence of an increased volume flow of blood to a lower extremity is taken to mean that all of the tissues of this extremity are receiving an increased circulation.

The distribution of the blood flow through tissues must be considered as applying to small volumes as well as to relatively large volumes of tissue. It has been clearly demonstrated that blood may be flowing freely through a capillary at a time when no blood is flowing through another capillary a small fraction of a millimeter distant.

FUNDAMENTAL PRINCIPLES OF THERAPEUTIC VENOUS OCCLUSION

After this definition of terms, I shall proceed with a discussion of the fundamental principles involved in the application of therapeutic venous occlusion to those conditions for which it has been used.

Venous obstruction as a therapeutic measure has been applied in three conditions: varicose veins with the attendant ulceration, arteriovenous fistula and simple arterial obstruction which may be either acute complete or progressive partial.

1. In instances of varicose veins associated with poor nutrition of tissues, the condition is probably one in which the poor nutrition of the tissues is the result of an already existent venous obstruction that operates to produce a diminished volume flow of blood through some of the superficial tissues. The only reason for the occlusion of the dilated veins which has ever been assigned, paradoxic as it may seem, is the ultimate removal of this existent venous obstruction. Further discussion of this particular phase of surgery of the venous system is not appropriate at this time.

2. In instances of arteriovenous fistula, the condition is one of an abnormal communication between the artery and vein through which the blood, destined for the tissues supplied by the artery distal to the fistulous opening, is shunted directly into the vein. In this condition, there are two circulations: a normal circulation through the capillary bed of the extremity and an abnormal circulation through the fistulous track. The arteries, capillaries and veins of the extremity are presumably normal. The anatomic defect lies solely in the fistulous communication between the artery and the vein. The physiologic defect lies solely in the diminution of the volume flow through the capillary bed because part of the arterial blood passes directly into the veins through the fistulous opening. From this, it is obvious that any therapeutic

measure must have as its prime object the diversion of the volume flow of blood of the abnormal circulation into the paths of the normal circulation.

3. In instances of simple arterial occlusion without arteriovenous fistula and without any demonstrable disease of the veins, the condition is one of a reduction of inflow of blood into the arterial tree distal to

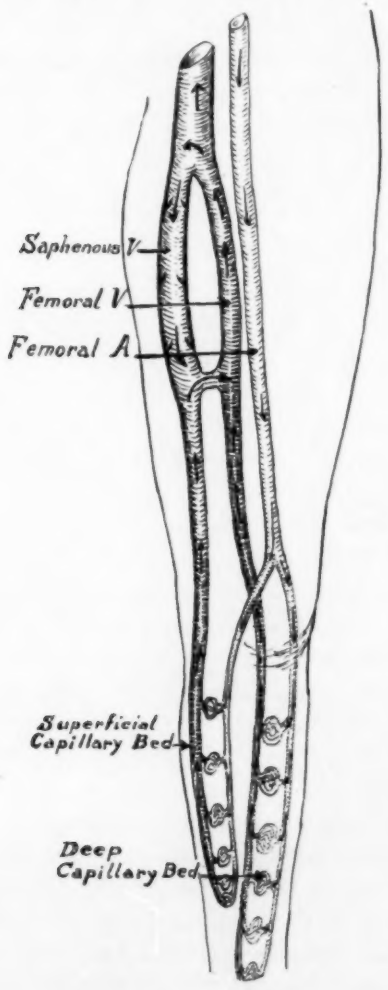

Fig. 1.—Conditions of the circulation of the extremity in the presence of varicose veins of the leg. The hydrostatic pressure in the absence of valves in the saphenous vein results in an increase in the venous pressure in the superficial veins. There is, therefore, a disproportion between the resistance offered in the capillaries of the superficial circulation and the capillaries of the deeper circulation. In this figure and figures 2, 3, 5, 6, 7, 8 and 9, *V* indicates vein and *A*, artery.

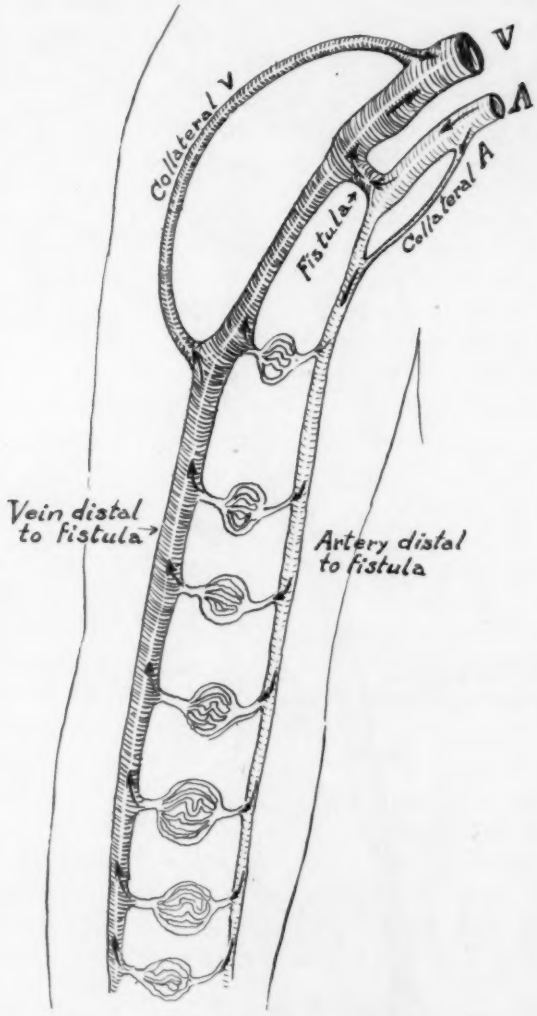

Fig. 2.—Conditions in the circulation of the arm with a fistulous opening between the axillary vein and artery. Blood may pass from the artery to the vein either through the capillaries of the arm or through the arteriovenous fistula. If the artery is obstructed just proximal to the fistulous opening, blood passing through the collateral arterial branch may also pass through the capillaries or the fistulous opening. Obstruction of the artery, therefore, merely results in a diminution in the volume flow through both circulations. The reduction of the volume flow through the capillary bed is probably in all instances proportionately greater than the reduction of the volume flow through the fistulous opening. Simultaneous ligation of the vein at the same level may diminish the volume flow of blood through the fistulous opening and increase the volume flow through the capillary bed. See also figures 4 and 9.

the point of obstruction without a corresponding reduction in the capacity of the outflow channels. There is no communication between the artery and vein other than through the capillary bed, and blood may flow from the artery to the vein through this capillary bed in all portions of the extremity. With an appreciation of the elementary principles of the flow of fluids through tubes, it becomes obvious that

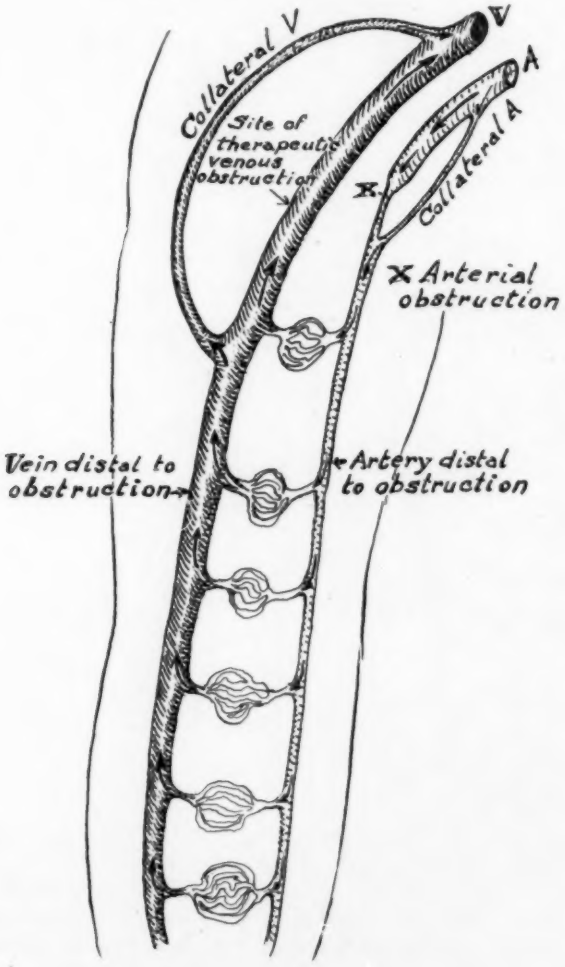

Fig. 3.—Conditions present in the circulation of the arm with simple arterial obstruction without arteriovenous fistula. No communication exists between the artery and vein except through the capillaries of the extremity. Therapeutic occlusion of the axillary vein makes it necessary for the return flow of blood to pass through the collateral vein. A difference of opinion exists as to the effects of the obstruction of the vein on the volume flow of blood through the capillaries. See also figure 7.

such a condition is of necessity associated with a diminution of volume flow through the tissues supplied by the obstructed artery and a diminished intravascular tension in the arteries, capillaries and veins. An artery may be completely obstructed suddenly by wound, ligature or embolus, or arterial obstruction may be the result of a progressive obliterating arterial disease.

It is primarily my purpose in this paper to inquire into the history of the development of the idea of therapeutic venous obstruction for arterial disease, to discuss the fundamental principles involved and to comment on the clinical applications. As has already been stated, the origin of the idea of purposeful obstruction of a healthy vein for its possible beneficial effects in instances of dangerous anemia from arterial occlusion has been attributed to experiences with arteriovenous fistula. The first advancement of this idea is usually attributed to Sir George Makins. I am convinced, however, that the idea had previously occurred to others. From a study of the literature, it seems that Makins did not clearly enunciate this idea until the delivery of his Hunterian Oration before the Royal College of Surgeons of England on Feb. 14, 1917,[6] and it is interesting that even at this time Makins included the evidence derived from the operative treatment of arteriovenous fistula as substantiating the conclusion that ligature of a healthy vein is to be recommended in instances of simple arterial obstruction. It is to the credit of Makins, however, that he apparently realized that ligature of the vein in arteriovenous fistula involved somewhat different principles, because he stated in his Hunterian Oration, "Evidence, moreover, exists that under certain conditions ligature of both artery and vein is a preferable procedure. The first example, *not an unmixed or simple one*,[11] may be sought in the results observed to follow the application of a single proximal ligature to the artery in cases of arteriovenous aneurysm.

"A more striking example is offered by the ligaturing of the popliteal vein alone for the treatment of senile gangrene of the foot by W. A. Oppel."

It is interesting that Halsted, also, apparently confused the principles underlying occlusion of the vein in the treatment for arteriovenous fistula with the principles underlying the therapeutic occlusion of the vein in instances of arterial obstruction without arteriovenous fistula.

The experience of von Oppel, to which Halsted ascribed the origin of the idea of ligation of the concomitant healthy vein in the presence of arterial obstruction, was briefly as follows:

> A man, aged 32, presented the clinical manifestations of a fistula between the axillary artery and vein due to a gunshot wound. Three operations were performed on May 5, 1905. During the course of the operations, frequent observations of the blood pressure were made by Korotkow.

11. Author's italics.

The first operation was completed at 11:30 a. m., and consisted of a double ligation and division of the axillary artery proximal to the aneurysm sac. Following this procedure, the arm became deathly pale and the blood pressure, zero.

The second operation was begun at 3:30 p. m., and finished at 4:30 p. m. The wound was opened. The axillary vein was divided above the aneurysm between ligatures. No change in the arm was noted by Korotkow. The operator then observed that pressure with the finger in the space between the stumps of the divided artery caused the arm to become red and the blood pressure to rise to 40 mm. A search was then made in the vicinity in which the pressure was exerted, and a large vein (v. axilaris profunda) was found. This vein was doubly ligated and divided. The blood pressure in the arm rose to 40 mm. The wound was then closed. When the dressings were applied, it was noted that the arm was getting pale. After the patient was returned to bed, the arm continued to be pale and severe pain developed.

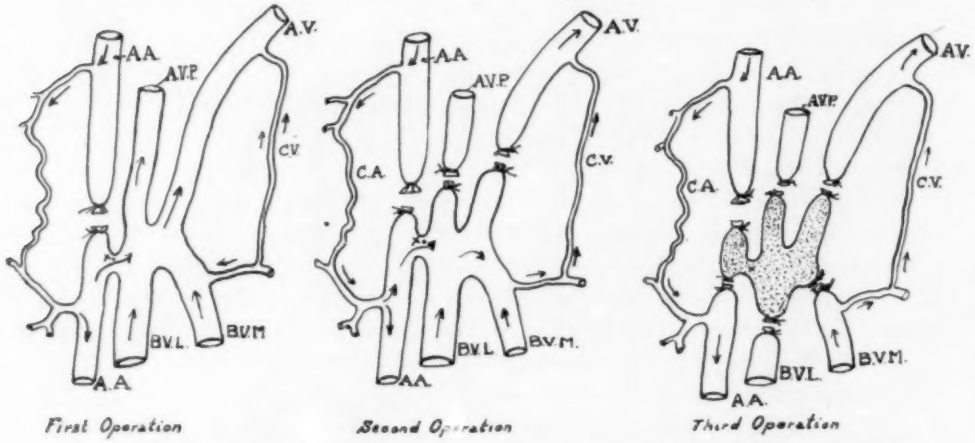

Fig. 4.—The operative procedure of von Oppel to which Halsted ascribed the origin of the idea of therapeutic ligation of the vein for prevention of gangrene. The diagrams are made from von Oppel's description. *A.A.*, axillary artery; *X.*, arteriovenous fistula; *A.V.*, axillary vein; *A.V.P.*, deep axillary vein; *B.V.L.*, lateral brachial vein; *B.V.M.*, medial brachial vein; *C.V.*, collateral vein circulation; *C.A.*, collateral arterial circulation. A description is given in the text.

The third operation was begun at 8:30 p. m., and consisted in a complete extirpation of the arteriovenous fistula. Immediately after isolation of the aneurysm sac, the arm became hyperemic and remained so for a period of twenty-four hours. Pain ceased, and an uneventful convalescence ensued.

I believe that von Oppel was in error in attributing the temporary improvement in the circulation of the arm observed during the course of the second operation to occlusion of the deep axillary vein. It would seem more likely that the pressure of the finger or the operative maneuvers of exposure of the vein resulted in temporary compression of the fistulous tract. I believe that he was also in error in his statement that the patient's condition was improved by the second operation.

The extreme pain which was present between the second and third operations would seem contradictory to this view.

This paper of von Oppel is an admirable record of the principles involved in the treatment for arteriovenous fistula. I am certain that any one who carefully reads this publication of von Oppel will be convinced that Korotkow, who was associated with von Oppel, had a clear conception of the principles involved in the ligature of the vein as a part of the operative procedure in the treatment for arteriovenous fistula. I believe that von Oppel had in mind only the conditions peculiar to arteriovenous fistula when he stated:

> So far as I know, up to the present time, there has been no mention of a rôle being played by the veins in relation to the origin of gangrene of the extremities.

Von Oppel's conception of the relationship of venous obstruction to the conditions associated with arteriovenous fistula is more clearly expressed in the following statement:

> When it is realized that the function of the collateral arterial circulation can be and is disturbed by the veins which suck arterial blood through the aneurysmal sac, then it is easy to draw the conclusion that those operative procedures should be chosen which will remove the aspirating effect of the veins upon the arterial blood, in other words, that procedure will be correct which, in the region of the aneurysm, *separates the bed of the arterial blood from that of the venous blood.*[11]
>
> In the separation of the bed of the arterial blood from that of the venous lies the principle of safe operative treatment of arteriovenous aneurysm of the peripheral vessels.

I believe that the first appreciation of the fundamental principles underlying therapeutic venous occlusion for arterial obstruction without arteriovenous fistula is to be found in the records of the experiences with an operative procedure opposite in nature to the operative method applicable to arteriovenous fistula.

In 1902, Carrel and Morrel attempted some experiments, the object of which was the reversal of the circulation in an extremity. During the same year, both Satrustegui [12] and Jaboulay attempted to produce a fistulous opening between the femoral artery and the femoral vein with the idea that this procedure would be beneficial in patients in whom gangrene of the extremity seemed imminent. In 1906, Carrel [13] showed conclusively that reversal of the circulation was possible in the experimental animal. In the same year, Hubbard [14] of Boston and Lilienthal [15] of New York reported instances of the application of this operative procedure for the treatment of impending gangrene of an extremity.

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12. Satrustegui: Bull. med., Madrid, 1902.
13. Carrel and Guthrie: Ann. Surg. **43**:203, 1906.
14. Hubbard: Ann. Surg. **44**:559, 1906.
15. Lilienthal: Ann. Surg. **45**:1, 1907.

In 1908, Wieting [16] of Constantinople described the indications, the operative technic and the results of an operation intended to reverse the circulation in the arteries and veins of an extremity in instances of arterial occlusion. In spite of the priority of the publications of Carrel, Hubbard and Lilienthal, this operation is still referred to in the literature as the Wieting operation. Following Wieting's report, there was much discussion as to the value of this operation as a therapeutic measure and as to the possibility of its actually resulting in a reversal of the direction of blood flow through the capillaries. The controversy between Wieting and Coenen [17] was particularly spirited. Wieting enthusiastically contended for the success of the operative procedure and discredited all experimental work which led to conclusions contrary to his own. The result of the controversy was the stimulation of a wider interest in the problems concerned.

The technic of the operative procedure which stimulated so much interest in the surgical treatment for diseases of the circulation of the extremities was variously modified. The original procedure consisted in a complete division of both the artery and the vein, transposition of the stumps of the vessels and end-to-end sutures. The operative technic was changed to one in which the vein was ligated, the artery divided, the distal stump of the artery ligated, and an anastomosis made between the proximal arterial stump and the vein distal to the ligature. The same result was accomplished by another modification of the operative technic, in which a lateral anastomosis of the artery and vein was made and the vein ligated proximal to and the artery distal to the fistulous opening. The final modification of the operation consisted of a lateral anastomosis of artery and vein and ligature of the vein proximal to artificial arteriovenous fistula.

The result of the interest in these operative procedures was the stimulation of a considerable amount of experimental work, of which some of the most interesting and valuable contributions have been overlooked because of their publication in the Russian language. It would seem, however, that von Oppel and his assistants were the first to call attention to the possibility that all the beneficial results which had followed the various operative procedures for reversal of the circulation had been due to venous obstruction rather than actual reversal of the circulation. Von Oppel, therefore, advanced the idea that the logical procedure in instances of arterial obstruction was the ligation of the vein. As evidence of the truth of this, he [18] reported in 1913 six instances of marked anemia of the lower extremity in which definite evidences of improvement had followed ligation of the popliteal vein.

16. Wieting: Deutsche med. Wchnschr. **34**:1215, 1908.
17. Coenen: Zentralbl. f. Chir. **38**:106, 1911.
18. Von Oppel: Vrach. Gaz. **20**:303, 1913.

It is to this report that Makins referred in his Hunterian Oration in which he first advocated the ligation of the vein in instances of arterial obstruction without arteriovenous fistula.

It would seem, therefore, as if the idea of therapeutic venous occlusion for simple arterial obstruction grew out of the experiences with an operative procedure which in reality is a procedure quite opposite to that usually considered the origin of the idea.

In passing it may be said that no better evidence of the lack of knowledge of the elementary principles of the circulation of blood could be cited than the fact that a condition recognized as the cause of gangrene

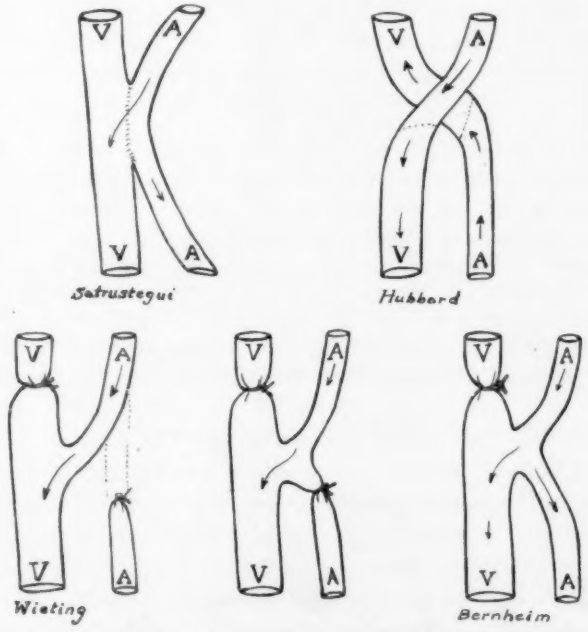

Fig. 5.—The various modifications of the operative procedure designed to reverse the circulation of an extremity.

was produced as a means of its relief. It is also worth while to call attention to the fact that during this period of awakened interest in therapeutic venous occlusion, there was apparently no clearcut definition of the different conditions to which it was deemed applicable. Von Oppel revealed his conception of the abnormal conditions of the circulation due to arterial obstruction when he wrote:[19]

As is known, angiosclerotic gangrene begins because of the lack of arterial blood supply. In instances of diminished circulation of an extremity, if the extremity is elevated, it becomes deathly pale and the characteristic ischemic pain

19. Translated from the Russian by Mr. Myer Epstein, Vanderbilt University Medical School and abstracted by the author.

ensues. If the extremity is then put into dependent position, hyperemia appears and the pain disappears. Why is this so? Observation of the blood pressure in the thigh in a patient with impending gangrene shows the blood pressure to be 30-50 mm. of mercury, which is about that of collateral arterial pressure after occlusion of the major arterial trunk. The blood pressure is, therefore, sufficiently low so that the hydrostatic pressure from the horizontal position is enough to cause cessation of the circulation. Maniewsky's experiments show that the Trendelenburg position may cause the pressure in the femoral vein to diminish nearly to zero. This is true if the arteries are healthy and the extremity is comparatively short. It is clear that with a diminished inflow of blood, this phenomenon would be exaggerated. Diminution in the venous pressure will result in a sucking into the vein of the collateral arterial blood supply and thus divert it from reaching the more distal aspects of the extremity. When the extremity is placed in the dependent position the weight of the blood in the arterial tree will be sufficient to cause a dilatation of the arteries, and the venous pressure will be increased. The advantage of the dependent position in preserving the nutrition of the tissues in patients with incipient gangrene is shown by the fact that these patients always prefer the extremity to be in the dependent position. In some instances, the patient cannot even endure the horizontal position. Both clinical and experimental observations show that ligature of the vein is associated with an increase in the pressure in the veins and arteries.

On these observations, I have recommended the ligation of the vein as a palliative procedure in instances of ischemic conditions, realizing that this procedure produces a reduction[20] in the circulation but is beneficial to the patient, at least for a time, in preventing the pain and helping to limit the gangrene. Ligature of the vein is beneficial not because the outflow is reduced, but because reduction in the outflow favorably influences the arterial circulation.

EXPERIMENTAL WORK

It would be impossible to review all the experimental work which has a bearing on therapeutic venous obstruction. Many important observations bearing on this subject are contained in the records of researches, the purpose of which was the study of other problems in the circulation. A brief review of a few of the most recent publications, devoted exclusively to the simultaneous ligature of the vein as a therapeutic measure in arterial obstruction, is sufficient for the object of this paper.

At the Conference of Inter-Allied Surgeons in Paris in 1917, van Kend[21] reported some experimental work, the conclusions of which were reported by Makins as follows:

> In carrying out a series of experiments made with the object of determining the indications and physiological basis for transfusion of blood, I have had the opportunity of measuring the blood pressure in limbs of which the main artery had been ligatured. The blood pressure was taken successively after the artery alone had been tied and again when ligature of the vein had been superadded.

20. In "reduction of the circulation," I believe that von Oppel had in mind the entire extremity and not its most peripheral aspects.

21. Van Kend: Compt. rend. conf. chir. internat., Paris, 1917, p. 348.

My observations confirm the view that has been expressed by Sir George Makins. In fact, plethysmographic tracings demonstrate clearly that a slight rise in the blood pressure in the limb follows the application of a ligature to a main vein after previous ligature of the artery. It appears then from the standpoint of the physiologist that to leave the main vein viable after occlusion of the main artery of a limb diminishes what may be called the residuary blood pressure maintained by the collateral circulation. If the contribution of the collateral circulation is allowed to remain with the main vein intact it is natural that the residuary blood pressure should fall. If this view be adopted, ligature of the vein as well as the artery should be recommended in order to retain the blood supplied in longer contact with the tissues. Thus the most satisfactory conditions for the maintenance of the nutrition of the organs are provided, because the obstacle to the return circulation provided by the ligature retains the blood for a longer period in the member.

Makins also quoted from a private communication received from Major Hamilton Drummond in which Drummond reported having found, from experiments made on loops of intestine of the cat, that gangrene more frequently followed ligation of the arteries alone than if both the arteries and the veins were obstructed.

The only experimental work which Halsted reported in his discussion of therapeutic venous occlusion for the relief of symptoms following arterial occlusion is the result of six experiments in which the blood pressure in the arteries distal to the arterial occlusion was measured before and after occlusion of the concomitant vein. It was found that venous obstruction was always followed by an increase in the intra-arterial tension and that release of the venous occlusion was followed by a diminution in the intra-arterial pressure.

Experimental work which was undertaken for the study of other physiologic changes than those of blood pressure was reported by Brooks and Martin [22] in 1923. In these experiments, it was found that the blood pressure in the artery distal to the point of occlusion was increased by the occlusion of the vein at the level of arterial occlusion. The pressure in the vein distal to the point of occlusion was increased relatively more than the pressure in the artery. The effect of the venous obstruction on the volume flow of blood in the tissues was studied by means of determinations of temperature in the tissue. It was found that after occlusion of the artery the temperature of the tissues, supplied by this vessel, was diminished and that further diminution occurred if the concomitant vein was also obstructed. From these facts, it was concluded that in instances of arterial obstruction occlusion of the concomitant vein resulted in an increase in intravascular blood pressure of all the vessels distal to the occlusions, and that the diminution of the

22. Brooks, B., and Martin, K. A.: Simultaneous Ligation of Vein and Artery, J. A. M. A. **80**:1678 (June 9) 1923.

volume flow of blood which resulted from the arterial occlusion was further diminished by the venous obstruction.

The effect of ligation of the concomitant vein on the incidence of gangrene in arterial obstruction was studied in a comparatively large series of experimental animals. It was found that the incidence of gangrene was decidedly less in those instances of obstruction of both artery and vein than in those instances in which the artery alone was obstructed.

From these experiments it was concluded that obstruction of the concomitant vein in the presence of arterial obstruction resulted in an increase in intravascular pressure but in a decrease in volume flow of blood through the tissues. The diminished incidence of gangrene, in spite of the diminished volume flow of blood, was attributed to the beneficial effects of the increased intravascular tension which probably operated in such a way as to produce a more equitable distribution of the blood flow.

More recent experimental work by Holman [23] and by Theis [24] has confirmed the effects of concomitant ligation of the vein on the blood pressure, but both Holman and Theis have reached a conclusion contradictory to that of Brooks and Martin concerning the effect of concomitant venous obstruction on the volume flow of blood. I believe that both of these investigators are in error in that they have not correctly interpreted their experimental observations. Both of these investigators have used the same method for estimating the effects of obstruction of the vein on the volume flow of blood. This method consists in observing the flow of blood from a cannula placed in the artery distal to the point of arterial obstruction. It was found that the amount of blood which flowed out through the cannula was increased if the vein was obstructed. This fact was interpreted by both of these investigators to indicate an increase in volume flow of blood through the tissues after occlusion of the vein. It would seem obvious that the increased flow of blood from the cannula in the artery distal to the obstruction would be the result of an obstruction to the outflow of blood and the corresponding increase in intravascular pressure and would thus be an evidence of diminished rather than increased volume flow through the tissues.

Other physiologic changes resulting from intentional occlusion of veins have been studied experimentally. Holman and Edwards, from experiments on dogs, found that the arterial blood pressure distal to the point of arterial obstruction was increased relatively more if the vein

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23. Holman, E., and Edwards, M. E.: New Principle in Surgery of Large Vessels, J. A. M. A. **88**:909 (March 19) 1927.

24. Theis, F. V.: Ligature of Artery and Concomitant Vein in Operation on Large Blood Vessels, Arch. Surg. **17**:244 (Aug.) 1928.

was occluded at a level nearer the heart than at the site of the arterial obstruction. These investigators believed that the occlusion of the vein at this relatively higher level caused an increase in the peripheral resistance of the circulatory bed supplied by the arteries furnishing the collateral branches, and thus caused a diversion of blood through the collateral paths of circulation into the arterial system distal to the point

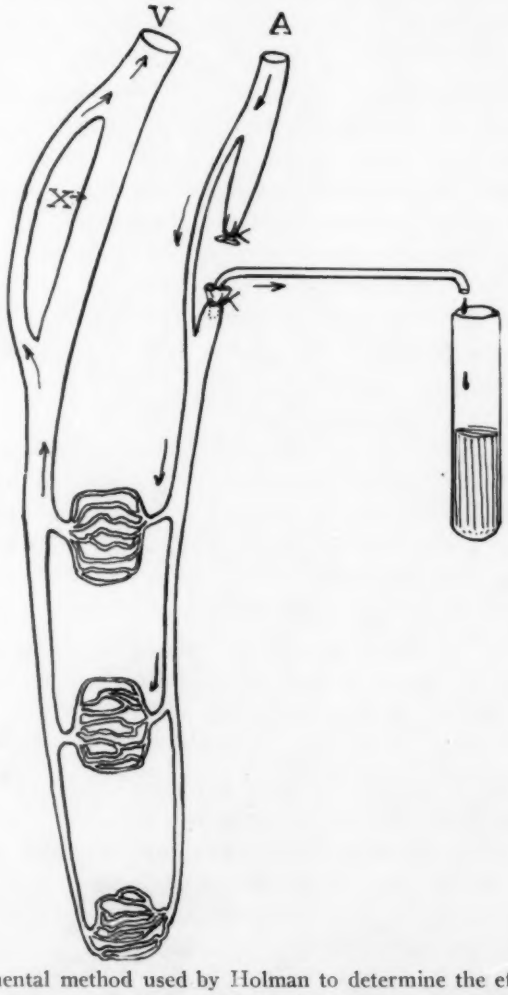

Fig. 6.—The experimental method used by Holman to determine the effects of ligation of the vein on the volume flow of blood through an extremity. It is obvious that obstruction of the vein at *X* would result in more blood flowing through the cannula. The fact that more blood flows from the cannula is not an indication of an increased volume flow of blood through the capillaries, but is evidence for the truth of the contrary conclusion.

of arterial obstruction. This conclusion is based on the fact that ligation of the vein at a higher level causes more increase in the intra-arterial pressure distal to the arterial occlusion than ligature of the

vein at the same level of arterial occlusion. This possibility was also considered by Brooks and Martin, but no experimental evidence could be found to substantiate it. As a matter of fact, their observations were such as to lead them to believe that this diversion of blood flow did not actually occur.

The effects of venous occlusion on the number and size of the paths of collateral arterial circulation about a site of arterial obstruction have been studied experimentally by Pearse [25] and by Theis.[24] Pearse found that ligation of the artery and vein was always followed by a richer collateral vascular bed than that following obstruction of the artery alone. On the other hand, Theis found that the collateral circulatory bed was better developed in those instances in which the artery and vein were occluded only if the determination was made immediately after the experimental vascular occlusion. In observations on the experimental animals, after a period of three weeks, the vascular bed was richer in those instances in which the artery alone was occluded.

The different results obtained by these investigators must have been due to a difference in the experimental methods used. It is worth while, however, to call attention to the fact that the size of blood vessels as determined by injection is not a reliable index of the actual volume flow of blood through tissues, and also to the fact that the condition of the circulatory bed three weeks after a sudden arterial occlusion is not necessarily important in the study of the cause of gangrene.

The conclusions from all observations concerning the physiologic effects of obstruction of a vein in the presence of arterial obstruction may then be briefly summarized as follows:

1. All observers agree that ligation of the concomitant vein in the presence of simple arterial obstruction is followed by an increase in the blood pressure in both the veins and the arteries distal to the level of obstruction.

2. Both experimental and clinical experience indicate that the incidence of gangrene is diminished.

3. In the attempts to explain the beneficial effects of therapeutic venous obstruction on the manifestations of arterial occlusion without arteriovenous fistula is found the confusion of ideas. Some are content to assign the beneficial effects to the "retention of blood in the tissues" or to a "restoration of the balance in circulation." With a clear conception of the fundamental principles of circulation of blood and the specific conditions under consideration, it becomes evident that the important differences of opinion, in regard to the effects of therapeutic venous obstruction, lie in the different views held concerning the influence of this procedure on the distribution of the volume flow of blood.

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25. Pearse: Ann. Surg. **86**:850, 1927.

It would seem as if all observers, except Brooks and Martin, believed that ligation of the vein was beneficial because this procedure increased the volume flow of blood in the capillary bed of the distal aspect of the extremity. If such is true, then the fundamental principles involved may be the same in therapeutic venous obstruction whether it is applied as treatment for arteriovenous fistula or for simple arterial obstruction.

If the conclusions drawn from the experiments reported by Brooks and Martin and other unpublished experiments of mine are true, the beneficial results of therapeutic venous occlusion in instances of simple arterial occlusion are not because blood flow is increased in the distal aspects of the extremity, but because the blood flowing through the distal aspect of the extremity is more equably distributed in the capillaries and is under greater tension in all the vessels. The actual amount

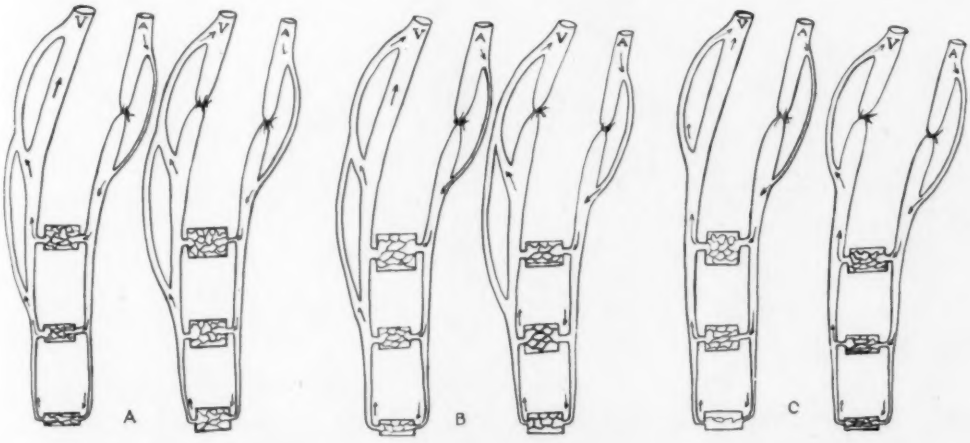

Fig. 7.—The different ideas which have been expressed as to the effect of simultaneous ligation of the vein on the volume flow of blood. In these diagrams the amount of the volume flow of blood in the capillary beds of the different aspects of the extremity is indicated by the vertical height of the rectangles. The distribution of the blood in the capillaries is indicated by the network in the rectangular spaces. The intracapillary pressure is indicated by the relative thickness of the lines of the network. In *A* it will be seen that ligature of the vein is followed by an increase in the amount of volume flow and intracapillary pressure in all aspects of the extremity. In *B* ligature of the vein is followed by a diminution in the volume flow through the proximal aspect of the extremity and an increase in the volume flow through the distal aspects of the extremity. The intracapillary pressure is increased in all aspects, and no change is indicated in the distribution of the flow in the capillaries. In *C* it will be noted that the volume flow of blood is diminished in all aspects of the extremity after ligature of the vein. The intracapillary pressure is increased in all parts. The distribution of the flow in the capillaries of the most distal aspect of the extremity before ligature of the vein is irregular, while after ligature of the vein it is homogeneous.

of the blood flowing through the distal tissues of the extremity is diminished by ligation of the vein. The principles involved in this view are entirely different from those concerned in therapeutic venous occlusion in the presence of arteriovenous fistula.

From a consideration of these facts, it would seem as if any existent difference of opinion was a matter of only academic interest, and that from the purely practical point of view the indications for therapeutic venous obstruction are clearly defined. Such is not the case. The conditions so far discussed have been considered from the point of view of their being fixed or unchanging. In the clinical application of the principles of therapeutic venous occlusion for arterial obstruction, it must be borne in mind that the situation is made more complex because the conditions are constantly changing and thus the remote

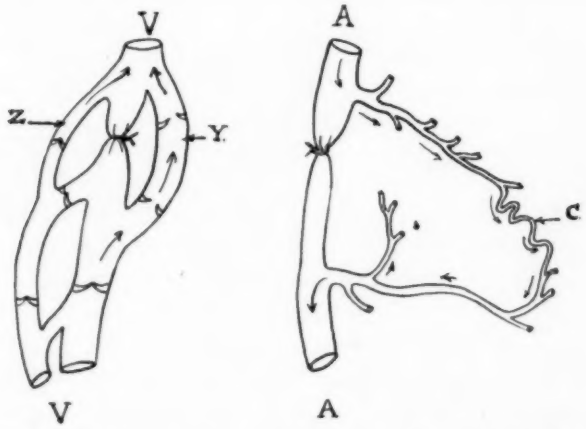

Fig. 8.—The differences in the conditions attending the development of collateral circulation in arteries (*A*) and in veins (*V*). It will be noted in *A* that the collateral circulation is from a branch proximal to the arterial obstruction through the collateral anastomotic branch (*C*) and thence in the reversed direction through the artery forming the distal aspect of the collateral arch. It is obvious that the amount of blood which passes through the collateral arch may continue to increase with an increase in the cross-section area of the arch. In *V* it will be noted that the collateral circulation about the obstruction is prevented from developing through the channel *Z* on account of the action of the valves. If it develops through the channel *Y* and this vessel subsequently enlarges, then its valves become incompetent.

as well as the immediate effects must be considered. In sudden arterial obstruction, from a wound or embolus, the greatest interference with the blood supply is immediate and without further complications, the blood flow through the anemic tissues may be expected to increase with the development of the collateral circulation. In instances of chronic arterial obstruction due to progressive obliterative arterial disease, there

may be a constant or intermittent change in the opposite direction. Also the amount of venous obstruction which is produced by the ligature of a vein does not remain fixed. Paths of collateral circulation develop about points of venous obstruction. Important differences exist between development of collateral circulation in veins and in arteries.

The sole source of energy for the propulsion of the blood stream through the arteries is the contraction of the heart. The development of collateral circulation about a point of arterial obstruction is necessarily associated with a reversal of the direction of flow through the artery constituting the distal aspect of the collateral arch.

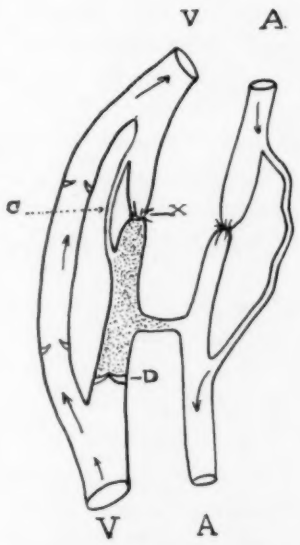

Fig. 9.—The effect of simultaneous ligation of the vein in the presence of arteriovenous fistula. In the conditions represented in the diagram, it will be seen that with ligation of the vein at *X* with the competence of the valve at *D* only such blood can pass through the fistula as could return to the heart through the vein (*C*). This would be true only if the pressure within the dotted area was insufficient to cause a breaking down of the valve at *D*. Subsequent increase in the pressure in the dotted area or dilatation of the vein at *D* would open new channels for the return flow of blood passing through the fistulous opening. This diagram illustrates a principle which may explain the temporary "improvement" sometimes observed in the treatment of arteriovenous fistula by simple proximal ligation of artery and vein. This condition may have been present immediately after the second operation in von Oppel's case.

The capacity of the collateral arterial circulation is therefore determined solely by the cross-section area of the collateral anastomotic branches.

The energy for propulsion of the blood through the veins is derived from three sources: 1. Diastole of the right side of the heart aspirates

blood from the adjacent large veins. 2. The blood may also be propelled through veins by the force of the left side of the heart transmitted through the arteries and capillaries. 3. In veins with valves, the flow of blood is accelerated by the alternate compression and relaxation of the vein by motion of the adjacent tissues. The operation of this factor is dependent on the fact that the valves in the vein permit the flow of blood in only one direction. The last factor is of great importance in propelling blood through veins of the extremity.

If collateral circulation in veins is considered in the light of these facts, it is obvious that a venous collateral circulation cannot develop by the reversal of the direction of the current through veins with competent valves. Furthermore, if the collateral circulation is through veins in the normal direction, then dilatation of these veins renders the valves inefficient.

These statements are in accord with clinical experience. If an extremity successfully passes through the immediate critical stage following simple arterial occlusion, a satisfactory permanent recovery may be anticipated. If, however, the manifestations of severe venous obstruction develop, convalescence is prolonged and often never complete.

It would seem, therefore, as if the remote effects of therapeutic venous obstruction must be taken into consideration. In other words, ligation of a vein might be the means of averting gangrene but the cause of subsequent chronic venous stasis. The clinical experience available is not sufficient for drawing definite conclusions. A letter from Sir George Makins, written in May, 1922, stated:

> I have seen some swollen extremities and varicose veins amongst the war pensioners, but in all the cases I have had the opportunity of examining, the injury to the vessels was accompanied either by very extensive wounds with loss of substance, or fracture of the femur or pelvis. I have not been able to regard these cases as a fair test, and no uncomplicated case of ligature of artery and vein with unsatisfactory after consequences has come under my notice.
>
> Still, I think the question of the ultimate condition of the limb must be considered undecided.

My own clinical experience leads me to believe that venous occlusion of an amount sufficient to be of value in the prevention of gangrene is often followed by manifestations of venous stasis from which convalescence is prolonged or incomplete.

From a consideration of all evidence available, I believe that the following statements are substantiated by the results of experimental study and clinical experience.

A. In operations for the cure of arteriovenous fistula, the vein should always be ligated in any of the following conditions: (*a*) If in the course of an operation the artery has already been ligated and

it is then found that the complexity of the condition present makes it seem beyond the skill of the operator to attempt to close the fistulous opening, or if the surgeon is uncertain of the success of his attempts, then ligation of the vein proximal to the fistula is imperative (fig. 9). (*b*) If an arteriovenous fistula has existed for a relatively short period and if it is necessary to obliterate the artery in order to close the fistula, then ligation of the vein is preferable in most instances and is always indicated if the artery is either the popliteal or the axillary. If an arteriovenous fistula is of long duration, the collateral arterial circulation is so abundant that even though it is necessary to obliterate the main artery in closing the fistula, ligation of the vein is unnecessary and even contraindicated. (*c*) There is a certain amount of justification in the view that ligature of the vein is always preferable in the treatment for arteriovenous fistula because of the danger of pulmonary embolism from thrombosis at the site of repair of the fistulous opening in the vein. I do not subscribe to this view.

B. In progressive arterial degenerative disease, associated with arterial obstruction, ligature of the vein is at most a palliative measure, the beneficial effects of which only occasionally justify its employment.

C. In instances of sudden arterial occlusion, therapeutic venous obstruction finds its most valuable applications.

If from traumatism or in the course of any operation it becomes necessary to ligate a large artery, simultaneous ligation of the concomitant vein should always be considered. If the artery ligated is the popliteal or axillary, I believe that ligation of the like named vein is definitely indicated. In instances of ligature of the femoral or brachial arteries, I am inclined to believe that simultaneous ligation of the vein in reality makes little or no difference. If the common femoral artery is ligated, I am inclined to believe that it is wiser to close the wound without ligating the vein, to watch the extremity carefully for signs of impending gangrene, and to ligate the vein only after such signs are evident. From my own experience, I believe that ligation of the common iliac artery is not an indication for ligature of the common iliac vein.

CONCLUSION

Simultaneous ligation of the vein is not to be considered the preferable procedure in all arterial ligations. It is to be applied only in those instances in which without ligation of the vein gangrene would be expected. In these instances, the probable immediate beneficial effects in preventing gangrene must be balanced with the possible remote ill effects of chronic venous stasis.

THE STRUCTURE OF BONE

WITH PARTICULAR REFERENCE TO ITS FIBRILLAR NATURE AND THE RELATION OF FUNCTION TO INTERNAL ARCHITECTURE *

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The microscopic anatomy of bone has been carefully studied by the older anatomists and histologists. All the controversial points have not been settled, and many questions still remain open. However, judging from the limited knowledge of bone structure that is prevalent now, except among those especially interested in the subject, one would think that this work had not been done. Perhaps there is a correlation between the dearth of recognized pathologic exposition of bone conditions and the lack of dissemination of histo-anatomic knowledge of bone. With the development of surgery of the bones and joints in recent years, many pathologic conditions, heretofore recognized only clinically, have become available for pathologic study. This work will be done mainly by surgeons and surgical pathologists, who will obviously base their interpretations on deviations from the normal. Since no

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detailed study of the structure of bone exists in American literature, it was thought that such an exposition might prove helpful to surgeons who are interested in bone as a tissue. The possibilities of improving the character of the work done on bone will be enhanced by a knowledge of the nature of the tissue.

Another reason why the study of bone is approached hesitatingly is that its histologic preparation is believed to be difficult. In another paper,[1] I have given directions for the preparation of bone for histologic study, and many of the methods could be applied to pathologic bone with great advantage.

In this paper, I am emphasizing that phase of bone structure which is least discussed. An effort is made to describe the general architecture of bone, and its fibrillar constitution is particularly emphasized. Osteoblasts have been only casually referred to, for when bone is already formed, they are structurally unimportant. The canal systems and their anastomoses have been discussed only in passing, and a description of the circulation has been omitted since it is unnecessary for an understanding of the structure of bone. The bone cells have been described in regard to their form but not in regard to function. Furthermore, these subjects are important enough to warrant special consideration.

COARSE-FIBERED OR PRIMARY BONE

Mammalian bone consists of collagen fibers and cells which are embedded in a cement substance containing calcium salts. There are essentially two types of bone, depending on the character and arrangement of the collagen fibers. In the bone which characterizes the skeleton of the human fetus and the new-born, the fibers are irregular and mainly coarse, and the cells are large, numerous and irregular. This type of bone practically disappears by the fourth year of life, and it is replaced by typical adult bone, which has for its distinguishing character fine fibers in lamellar arrangement. In different species of lower mammals the time interval, during which the coarse-fibered bone is replaced by lamellar bone, varies.

Phylogenetically, coarse-fibered bone is the older and more primitive bone tissue. Some of the lowest vertebrates retain this type of bone for their adult skeleton, and it represents the greatest part of their periosteally formed bone. Coarse-fibered bone is the type of bone generally seen in ossified fibrous tumors and in osteogenic sarcomas, and it is the first bone formed in the repair of a lesion of the bone even in the adult. In short, whenever new bone is being formed, except in the case of the normal reconstruction that goes on constantly in lamellar

1. Jaffe: Methods for the Histologic Study of Normal and Diseased Bone. Arch. Path., to be published.

bone, it is first formed as fiber bone, which may later be replaced by lamellar bone. Coarse-fibered bone persists in adult man in those places in which tendons are attached to bone and, according to Meyer, in the bony capsule of the labyrinth of the ear. Sometimes small nests of fiber bone with thick Sharpey fibers may be seen in adult cortical bone.

When bone is first formed in the fetus, either as membrane or endochondral bone, it consists of trabeculae containing coarse fibers and cells between which lies a loose, vascular, connective tissue in which the primitive marrow develops. The structure of coarse-fibered bone may be studied in older fetuses and in the new-born in which it is laid down beneath the periosteum or is deposited on the calcified cartilaginous trabeculae in endochondral ossification. If one examines a cross-section of the diaphysis of a tubular bone or the mesodermal bone of the jaw of a 6 months fetus, it shows numerous haversian canals which are only rarely circular in cross-section, being generally somewhat elongated. Wide anastomoses are often seen between them. Irregular bony trabeculae lined by osteoblasts are present between the canals. The main direction of the haversian canals is longitudinal, as it is in adults (fig. 1). Immediately about the haversian canals the bone is least dense, but the bone between two adjacent haversian canals is more dense. Here the fiber bone consists of closely meshed, interlacing and decussating fiber bundles in which numerous irregularly disposed bone cells are embedded. Most of the fibers are thick and coarse. The fiber bundles measure from 2 to 27 microns across, but average from 12 to 15 microns. The larger bundles consist of groups of smaller bundles. The bundles are separated from each other by a layer of cement substance, or by some disordered fibrils. The marked irregularity of arrangement of these fibers is as much a characteristic of this bone as the thickness of the fibers. The mass of thick decussating fibers between two haversian canals was designated by Gegenbaur [2] as Wurzelstock (fig. 2).

The coarser fibers of primary bone are better known as Sharpey fibers. While present in great numbers in the bone of the fetus and new-born, few are contained in adult bone. They were described by Sharpey in adult bone in the sixth edition of Quain's anatomy and have also been studied extensively by Mueller [3] and Koelliker.[4] Developmentally, their origin is different from that of the fine fibrils of lamellar

2. Gegenbaur: Ueber die Bildung des Knochengewebes, Mitt. Jen. Ztschr. f. Med. u. Naturwiss. **1**:341, 1864; **3**:206, 1867.

3. Mueller: Ueber Sharpey's durchborende Fasern im Knochen, Wuerzburg naturwiss. Ztschr. **1**:296, 1860.

4. Koelliker: Handbuch der Gewebelehre, 1889, vol. 1.

bone, since they are derived from the periosteum. Von Ebner [5] and others described them as connective tissue and collagenous fibers, and Koelliker expressed the belief that some of them, particularly the thicker ones, may be partially calcified. In the fetus and the new-born, they are best seen in longitudinal sections of the periosteal trabeculae of tubular bones. By the fourth year, their appearance and number are the same as those in adult bone.

Fig. 1.—Part of a cross-section through the diaphysis of a long bone of a 6 months fetus, showing fibrous periosteum, osteoblastic periosteum, irregular trabeculae lined by osteoblasts and large haversian spaces with primitive marrow.

Numerous anastomosing bone cells are embedded between the fiber bundles, either singly or in groups. These bone cells are larger than those of adult bone. The lacunae, therefore, are larger and somewhat irregular. The processes of the bone cells of coarse-fibered bone are shorter, thicker and fewer than those of adult bone cells, and the canaliculi are correspondingly shorter and wider. If the lacunae of

5. Von Ebner: Ueber den feineren Bau der Knochensubstanz, Sitzungsb. d. k. Akad. d. Wissensch. **71-72**:49, 1875.

the bone cells are closely packed, they may fuse and produce large spaces into which parts of the fiber bundles or groups of disordered fibrils may enter. In recently formed fiber bone, the cells are more numerous and newly formed trabeculae underneath the periosteum may consist of so many cells that the bone has a fenestrated appearance. This is also true of the fiber bone removed from the neighborhood of healing fractures, examination of which will show trabeculae that consist preponderantly of irregularly dispersed bone cells, held in the meshes between matted fibers (fig. 3).

A section through a long bone of an infant in the region of endochondral ossification shows the difference in structure between the

Fig. 2.—The thick fibers of the Wurzelstock between the haversian canals. Frozen section from skull of an infant, aged 12 weeks. Bielschowsky silver stain.

primary coarse-fibered bone deposited on the calcified cartilage cores and the primary coarse-fibered bone formed by the periosteum. Primary endochondral bone is similar in fibrillar structure to the periosteal primary bone, except that, as has been observed by von Ebner, the thick centrally placed mass which was described as Wurzelstock by Gegenbaur is absent, its place being occupied by calcified cartilage cores. The line of junction between the cartilage core and bone is irregular and corresponds in many respects to the cement lines of adult bone. Otherwise, cement lines are practically absent.

In man the character of the fiber bone rapidly changes, and soon after birth a cross-section through the diaphysis of some of the bones will show that the haversian canals have narrowed considerably in

diameter, that there is a tendency for the fibers to be disposed more regularly, particularly about the canals, where the fibers are thinner, and that the bone cells near the canals appear more like the bone cells of lamellar bone. A few thick fiber bundles may course through the fibrils arranged around the haversian canal and may enter the canal.

The problem that is still controversial is the part that osteoblasts play in the formation of fiber bone. Many believe that coarse-fibered bone results from a bony transformation of mesenchymal or embryonal connective tissue, during which calcium salts are deposited between the

Fig. 3.—Newly formed trabeculae under the periosteum showing numerous irregularly disposed bone cells. This should be compared with figure 5.

fibers, and in the formation of which osteoblasts play no part. They believe that in the formation of this bone the connective tissue cells become transformed into bone cells. There are others who believe that the primary bone develops everywhere from the mesenchyme through the medium of osteoblasts, and not indirectly, as already described above, from calcification and ossification of connective tissue. Lubosch [6] was in full agreement with the opinion of Schaffer [7] that all bone arises

6. Lubosch: Die Osteoblasten und ihre Metamorphose, Ztschr. f. mikr. Anat. **12**:279, 1928.

7. Schaffer: Die Verknoecherung des Unterkiefers und die Metaplasiefrage, usw., Arch. mikr. Anat. **32**:266, 1888.

through the participation of osteoblasts which are specific differentiated bone-forming cells of the embryonal mesenchyme. I am in accord with this view so far as it pertains to skeletal bone, and believe that all the embryonal primary bone is of osteoblastic origin. But how the osteoblasts form bone, that is, what the relation between the osteoblasts, fibrils, cement substance and the deposition of calcium is, are involved questions, the answers to which are not necessary for an understanding of the structure of fiber bone.

FINE-FIBERED OR LAMELLAR BONE

Lamellar bone replaces the original coarse-fibered bone, and by about the fourth year nearly the entire human skeleton consists of lamellar bone. Heuler,[8] in studying cross-sections of the shaft of the human femur and humerus, found that by the eleventh year the adult structure is reached and maintained with no change from then on. It has been mentioned that coarse-fibered bone is the more important in the skeleton of a vertebrate, the lower it stands in the animal scale and the smaller its body. Gebhardt expressed the belief that the degree of formation of lamellar bone is related directly to the size of the skeleton, but of this there is some doubt.

Previous to birth the vascular spaces in the bone cortex are relatively large, and a coarse reticular structure is present. The size and shape of the vascular spaces at this time vary with the part of the shaft examined. The spaces are larger the nearer they are to the epiphyseal cartilage plate, and in the middle of the shaft of the diaphysis the spaces nearer the periosteum are larger. The primary haversian canals of coarse-fibered bone are the first spaces formed when bone is produced by the periosteum. In the course of development, many of these primary canals under the periosteum become confluent because of resorption of their walls and become the longer and more irregular haversian spaces. Shortly before and after birth osteoblasts deposit lamellae of fine-fibered bone on the coarse-fibered walls of these spaces, forming haversian systems. A haversian system consists of a central canal with bone deposited concentrically about it. At the same time, new trabeculae of coarse-fibered bone are formed subperiosteally. *A* and *B* of figure 4 are cross-sections through the middle of the shaft of an infant, aged 12 weeks, showing subperiosteal fiber bone with wide subperiosteal haversian spaces. Deeper in the cortex the canals have become reduced in size and some are surrounded by lamellar bone, though between the canals considerable coarse-fibered bone is still present. These first and

8. Heuler: Korrelation zwischen Alter und Knochenstructur, Ztschr. f. Zellf. u. mikr. Anat. **7**:41, 1928.

true haversian lamellar systems are also of temporary nature, and are resorbed and serve for the formation of new haversian systems. The process of formation and dissolution continues until the adult stage is reached, and even then a constant but slow reconstruction is continually taking place.

Beneath the periosteum, lamellar bone is laid down, and the surface of the bone finally consists of a series of lamellae. But various authors

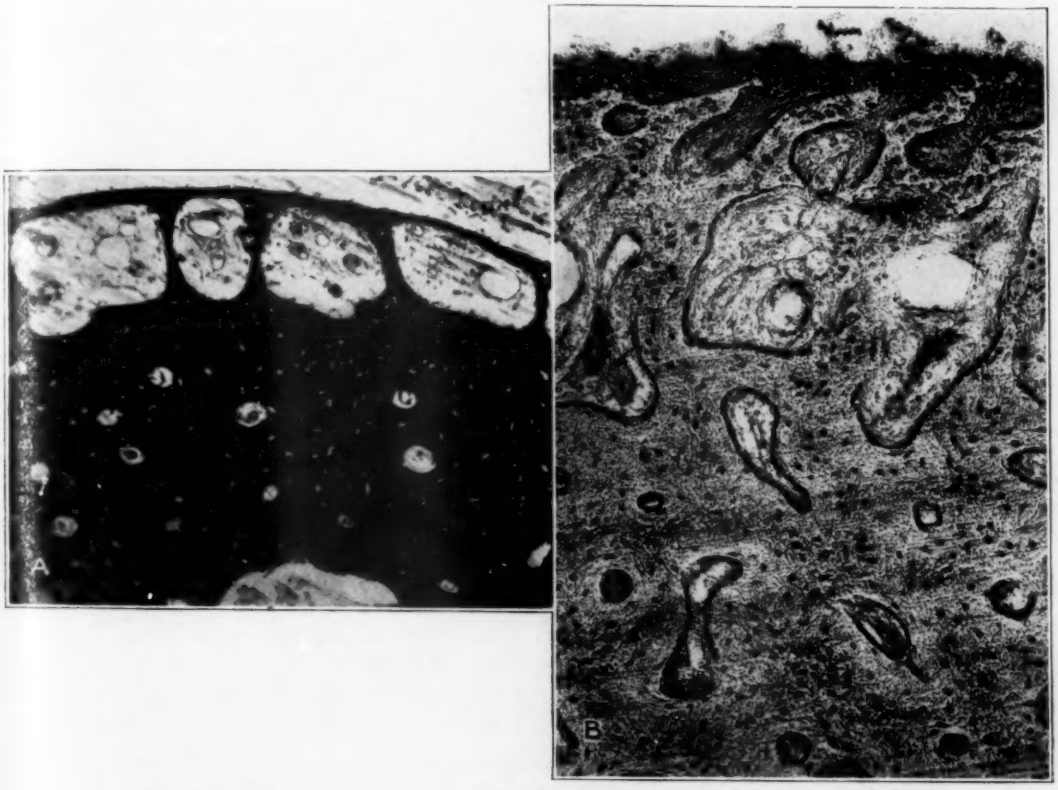

Fig. 4.—*A*, part of a cross-section of the diaphysis of a long bone of an infant, aged 12 weeks, showing wide subperiosteal haversian spaces underneath a thin layer of subperiosteal bone. Deeper in the cortex, the smaller haversian canals are seen. Carmine and Weigert's fibrin stain. *B*, part of cross-section through another long bone of the same infant. It is an unstained frozen section of von Ebner decalcified bone, showing the periosteum above with the subjacent large haversian spaces, and the deeper haversian canals, some of which are surrounded by a few concentric lamellae.

have described the first appearance of subperiosteal lamellar bone at different times. In long bones Schwalbe [9] found fiber bone beneath the

9. Schwalbe: Ueber postembryonales Knochenwachstum, Sitzungsb. d. med. naturw. Gesellsch. zu Jena, 1877, p. 11.

periosteum until the fourth year. Koelliker reported subperiosteal lamellar bone as early as the first year after birth. Recently, authors have described subperiosteal lamellar bone in the first months after birth. I saw no subperiosteal lamellae in cross-sections through the shafts of two long bones of an infant, aged 12 weeks, though lamellar bone was present deeper in the cortex. On the larger endochondrally formed trabeculae in the marrow cavity, some lamellar bone is seen after birth.

General Structure of Lamellar Bone.—When an adult tubular bone is sawed open longitudinally, parts of it are seen to be dense and compact in texture and other parts, spongy. Accordingly, two forms of adult osseous tissue are distinguishable, compact and spongy bone. On closer examination, however, especially with the aid of a magnifying glass, it will be found that bone is everywhere more or less porous, and that the difference between compact and spongy bone depends in part on the different amounts of calcified tissue compared with the size and number of open spaces in each. The cavities are small in the compact parts of the bone, with much dense bone between them, while in the spongy texture the spaces are large, and the intervening bony partitions are thin and slender. When both compact and spongy bone are present, as, for instance, in the upper end of a tubular bone, there is no abrupt limit between the two; they pass into one another by degrees; the haversian spaces of the compact bone widen out, and the reticulations of the cancellated bone become closer as they approach each other.

In all bones, the outside is compact and forms a shell or crust of varying thickness, while the spongy bone is contained within. In a long bone the large round ends are made up of spongy tissue with only a thin coating of compacta; in the hollow shaft, on the other hand, spongy bone is scanty or absent, and the walls are formed of compact bone, which increases in thickness toward the middle, at which point the girth of the bone is usually least. In flat bones, such as those of the skull, the compact tissue forms two plates or tables, enclosing between them the spongy texture, which in such bones is named diploe. The short round bones, as the bones of the wrist, are spongy throughout, except at their surface, where there is a thin crust of compact substance. In the irregular or mixed bone, as, for example, a vertebra, the two types of bone have the same general relation to each other, but the relative amount of each in different parts, varies.

THE COMPACTA

A cross-section of the cortex of a bone shows that there are several ways in which the lamellae are arranged in the compacta. Some are deposited about blood vessels, as the haversian lamellae, to form the

haversian systems, and others do not surround blood vessels but are deposited by periosteum or endosteum, and are known as the outer and inner concentric or ground lamellae. In addition there are the interstitial lamellae which fill in the spaces between the haversian systems (figs. 5, 6 and 7).

In making comparative studies, it becomes evident that the structure of the compacta varies considerably. For instance, the structure was found to be quite different in various segments of the same circumfer-

Fig. 5.—A ground disk of the compacta of the diaphysis of a long bone, showing the outer ground lamellae, haversian systems and interstitial lamellae.

ence of the diaphysis. It was also found that sections through the shaft of various bones of the same person show varying degrees of development of the ground, interstitial and haversian lamellae. Examination of sections of corresponding bones of the rat, guinea-pig and rabbit shows marked variation in the degree of development of the different types of lamellar bone. For instance, a section of the tibia of the rat shows marked development of the outer ground lamellae, the haversian lamellae being few and the inner ground lamellae also being poorly developed. A section through the same bone of a guinea-pig shows better development of the inner ground lamellae, fewer outer

ground lamellae and better developed haversian lamellae. A section through the tibia of a rabbit shows still better development of the haversian lamellae at the expense of the ground lamellae. The dog shows haversian systems still more highly developed, but generally not as irregular as the haversian systems of the human cortex.

The Canals.—A system of preformed canals in the cortex carries blood through the compacta. These canals are known as the haversian canals, Schwalbe's canals, and the communicating canals, some of which are true Volkmann's canals. The haversian canals are found in the compacta, surrounded by concentric lamellae and running longitudinally through the bone. The canals of Schwalbe are found running circum-

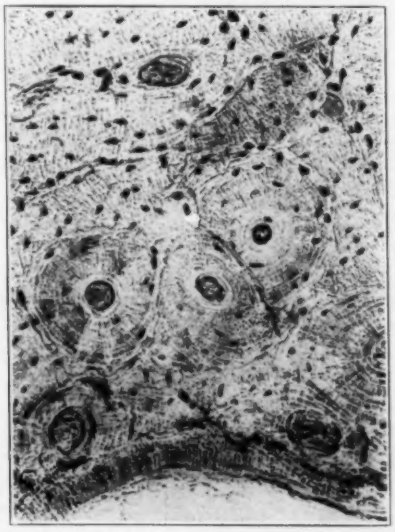

Fig. 6.—Another portion of the ground disk, in figure 5, showing the inner ground lamellae below, haversian systems and interstitial lamellae.

ferentially between the ground lamellae or transversely through them. The communicating canals connect the haversian canals; they run transversely or diagonally through the shaft and sometimes, when they are not preformed, are true Volkmann canals.

Haversian Systems.—The haversian system constitutes the basic structural unit of lamellar bone, and a knowledge of its structure and formation is necessary for a clear understanding of the anatomy of adult bone. The formation of this type of bone is ascribed to osteoblasts by all workers who believe that the osteoblasts are bone formers. The osteoblasts deposit the haversian lamellae in layers on the coarse-fibered bone about the walls of the blood vessels in the primary marrow

spaces, thus forming the first haversian systems. The osteoblasts are carried into the fiber bone by the vessels. I agree with those who believe in the specificity of the osteoblasts in the formation of lamellar bone. But how the various constituents of the lamellae are formed opens up questions that I do not want to discuss here, for it involves complex and unsettled problems of bone formation. It seems to me that for the present, it is best to visualize the process of the replacement of coarse-fibered bone by lamellar bone as follows: The osteoblasts about the vessel deposit a layer of osseous material on the fiber bone. As a result, a cylinder is formed which is known as a haversian lamella. As the lamellar bone is deposited on the fiber bone, the latter gives way. The replacement does not occur through the medium of erosion or osteoclasts, but as a process of substitution, in which the fiber bone tacitly disappears. Certain of the chemical components of the fiber bone

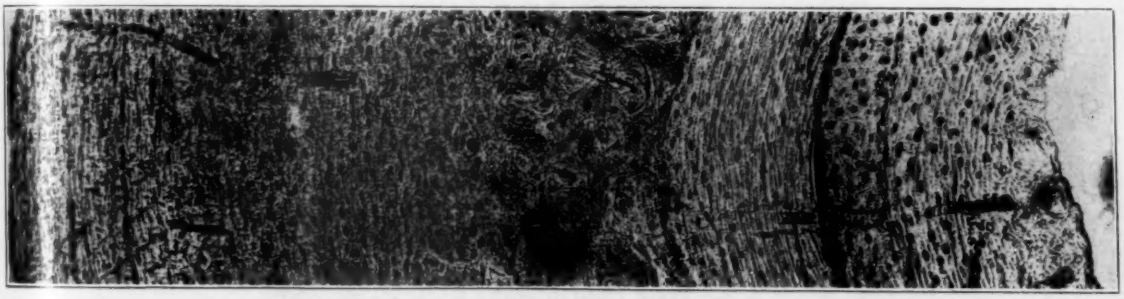

Fig. 7.—Segment of a cross-section through the diaphysis of the tibia of a guinea-pig, showing the well developed outer ground lamellae, a narrow zone of haversian systems, and well developed inner ground lamellae. Unstained frozen section of von Ebner decalcified bone.

are utilized by the lamellar bone in the reconstruction. Marchand,[10] in describing the creeping replacement of transplants to which this process is akin, said that when the first lamella is formed, one cell process from each cell of the ring of osteoblasts about the vessel enters it. A few cells leave the original row of osteoblasts, become enclosed in the bone ground substance and become bone cells. The original osteoblastic row is again closed by multiplication of its cells; the process is repeated; a new cylinder is formed between the first cylinder and the blood vessel, just external to the osteoblastic layer. Cells from the osteoblastic layer invade this new bone ground substance, and a second lamella is completed. In this way the haversian columns become stratified structures forming haversian systems made up of haversian lamellae, traversed by a central canal containing vessels.

10. Marchand: Prozess der Wundheilung, Deutsche Chir., 1901, vol. 16.

How the first lamella expands to accommodate the succeeding ones is not made clear in the literature. It is evident that the lamellae are being formed rapidly and that they are not rigid when formed, so that expansion by pressure of the newer lamellae is possible. Also, in the formation of the haversian systems, as the lamellae are laid down, the vessel space is encroached on and the original space is reduced in size, for the haversian canals of normal lamellar bone are generally much smaller than the vascular spaces of fiber bone. Thus the lamellar bone formed about the vessel probably grows centrifugally and centripetally.

The lamellae about the haversian canals are disposed in a ringlike manner, but sometimes they do not extend entirely around the canal. This occurs where one canal is anastomosing with another. In the region of the anastomosis, the lamellae frequently surround the anastomotic vessel. The size and shape of the haversian systems of human bone vary considerably on account of the reconstruction that is constantly taking place. In general it may be said that the widest haversian canals are surrounded by the fewest lamellae, the medium-sized canals by the largest number of lamellae, while the smallest canals also possess thin walls, though they are thicker than the walls of the widest canals.

According to Koelliker, the thickness of the individual lamellae of human bone varies from 4.5 to 11 microns, the average thickness being from 6.7 to 9 microns. Von Ebner gave from 3 to 5 microns as the average thickness of the lamellae, but most were 3 microns thick. My own figures approach more nearly to those of Koelliker. The number of lamellae in each haversian system is, as a rule, from 8 to 15; sometimes only 4 or 5 are present; sometimes from 18 to 22 are seen. The haversian systems constitute most of the thickness of the diaphysis in man and are separated from the periosteum by the outer ground lamellae. Sometimes, the haversian systems even penetrate the outer ground lamellae, while the latter may sometimes enter between the more superficial haversian systems. When inner ground lamellae are present, they separate the haversian systems from the marrow cavity.

Bone Cells.—The lamellae are traversed by the canaliculi and processes of the bone cells while the lacunae, containing the bone cells, are either in the lamellae near the borders or between two lamellae. Most of them are between the lamellae. The lacunae of adult bone are minute elliptic recesses in the bone and extending from them are fine pores or tubes called canaliculi which issue from their cavities. These canaliculi are numerous, slender and relatively straight. They come off from the surfaces of the lacunae, as they may be seen in both longitudinal and cross-sections. They are more numerous in cross-sections. The lacunae present some differences in shape, but in a cross-section they appear irregularly fusiform, for the most part, and lie

nearly in the same direction as the lamellae between which they are situated. That is, the little cavities are flattened and extend conformably with the lamellae. When the bone is cut longitudinally, sections of the lacunae will still appear fusiform and lengthened out in the direction of the lamellae. The canaliculi, on the other hand, pass across the lamellae and communicate with those of the neighboring lacunae so as to connect the lacunae with one another (fig. 8 *A* and *B*). Since the canaliculi of the most centrally placed lacunae open into the haversian canals, a system of continuous passages is established by these tubules and their lacunae, along which fluid may be conducted from the haversian canal

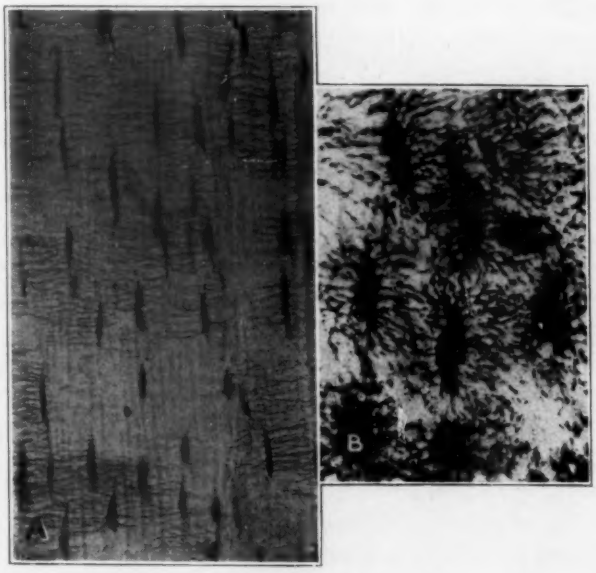

Fig. 8.—*A*, bone lacunae and canaliculi of human bone, showing anastomoses of canaliculi. A longitudinal ground disk mounted in balsam. *B*, lacunae and canaliculi of human bone in a ground disk impregnated with silver according to the method of Matschinsky.

through its surrounding lamellae. It seems probable that the chief purpose of these minute passages is to convey nutrient fluid from the vascular haversian canals through the mass of hard bone that lies around and between them. In a like manner, the canaliculi open into the main marrow cavity and into the marrow spaces between the spongy trabeculae, for the spongy bone also contains lacunae. Each lacuna is occupied by a nucleated bone cell, the walls of which are applied to the inside of the cavity, while branches or tubular protoplasmic processes line the canaliculi and anastomose with intracanalicular branches of similar cells, which occupy neighboring lacunae.

On the surface of the haversian canals osteoblasts are seen, varying in number in the different canals. In adult lamellar bone, just a few are seen.

The Fibrillar Structure of the Haversian Lamellae.—Each lamella consists of innumerable fibrillae embedded in a cement substance, with calcium salts impregnated between the fibrils. Together these elements constitute the ground substance of the bone. If a cross-section of the cortex, in the form of a ground disk or a frozen section, is examined under the polarizing microscope, oil immersion being used, the lamellae present a stippled appearance, each point being 1 micron or less in diameter. The points are closely applied and represent cross-sections of individual bone fibrils. Unless the section is in focus, the stippled appearance is not seen. It may be brought out by pressing the slide vigorously against the stage of the microscope. A longitudinal section of the bone examined in the same way shows a serially striated appearance. In such a section, the striations also represent individual fibrils. Heating the section will bring out the fibrillar structure a little better. The decalcification of bone, hydrochloric acid being used, in no way injures the fibrils.

That the fibrils of bone possess the qualities of fibrils of connective tissue may be seen by the treatment of sections with acetic acid, which causes the fibrils to swell and disappear. If they are countertreated with alkalis the fibrils will reappear, but with overtreatment with alkalis the fibrils will again disappear. Another fact in favor of the similarity of connective tissue and bone fibrils is that collagen can be extracted from both bone and connective tissue.

It is generally believed that the inorganic salts of the ground substance do not become chemically combined with the collagenous fibrils. While a cement substance is believed to be present between fibrils, the unequivocal demonstration of the nature of this material is difficult. Its existence is inferred from the fact that in disks and sections the fibrils are separated and seem to be embedded in a supporting material. Further evidence of the existence of cement substance is the observation of von Ebner that incineration of bone leads to the destruction of the fibrils, but the supporting material remains, and in it air-filled spaces formerly occupied by the fibrils may be demonstrated. The cement substance is supposed to consist of an organic base containing calcium salts. It is apparently the homolog of the cement substance of connective tissue. Since von Ebner made the classic studies of the fibrillar structure of lamellar bone, practically nothing new has been added. However, Henle, and Sharpey before him, had recognized the fibrillar nature of bone.

The uniformity of the arrangement and direction of fibrillar bundles and the delicacy of the fibrils are characteristic of lamellar bone. This

contrasts strikingly with fiber bone, in which the bundles are coarse, running parallel or interlacing. It is typical of lamellar bone that its fibril bundles are arranged concentrically. In haversian systems, this concentric arrangement is related to the haversian canal. In ground lamellae the concentric arrangement is related to the main marrow cavity, and in spongy bone the arrangement of the lamellae is related grossly to marrow cavities between the trabeculae (fig. 9 *A* and *B*).

The arrangement of the fibrillae in each lamella has been variously described. The question as to whether the fibrils and fibril bundles intertwine has been the main point on which there has been a difference

Fig. 9.—*A*, ground disk of cross-section of human bone as seen under the polarizing microscope. *B*, higher magnification of *A*, showing details of fibrillar structure of three haversian systems and some interstitial lamellae.

in opinion. Koelliker believed that fibrils were straight, and were arranged in closely adjacent straight bundles which did not connect. According to him, these bundles are perforated by numerous canaliculi, but their fibrils do not intertwine. Opposed to this view are the observations of von Ebner and Weidenreich.[11] Von Ebner described the fibrils as straight but intertwining, while Weidenreich said that the individual fibrils are twisted spirally and, in addition, intertwine.

11. Weidenreich: Knochenstudien I. Teil: Ueber den Aufbau und Entwicklung des Knochens und den Charakter des Knochengewebes, Ztschr. f. d. ges. Anat., part 1; Ztschr. f. Anat. u. Entwicklungsgesch. **69**:382, 1923.

According to the latter, each fibril bundle in lamellar bone contains only a few fibrils.

The fibril bundles of most lamellae, according to von Ebner and Gebhardt,[12] run spirally, making turns around the haversian canal at angles of approximately 45 degrees, but the degree of the angle may vary from 1 to 90 degrees in the different lamellae of each system, and some of the lamellae may have their fibers parallel to the canal. The general direction of the fibrils changes in each lamella of the haversian system, so that in one lamella the fibril bundles may run clockwise and in the next, counterclockwise, but in some haversian systems a few of the adjacent lamellae may show fibrils running in the same direction

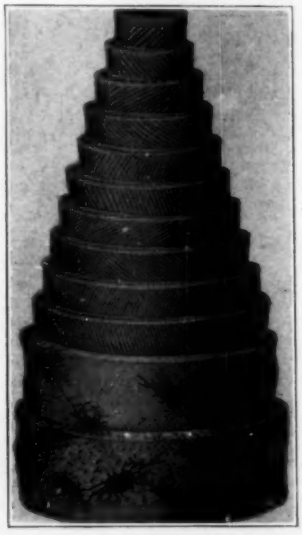

Fig. 10.—Diagrammatic representation of a haversian system, showing the haversian canal, the layers of lamellae with the fibrils running in alternating directions, and the bone cells with their anastomosing canaliculi. After Braus.

(fig. 10). It is believed by most observers that some of the fibrils of each lamella enter the adjacent lamella and in this way bind the lamellae together.

It must be remembered that the haversian lamellae, though disposed about central canals which run longitudinally, are frequently not completely concentrically arranged about the canal, because the diameter and the direction of the lumen of the canal may vary. Some lamellae do not completely encircle the canal because the haversian systems are being altered by reconstructional changes going on in them, which leads

12. Gebhardt: Ueber funktionell wichtige Anordnungsweisen der groeberen und feineren Bauelemente des Wirbeltierknochens, I & II, Arch. f. Entwcklngsmechn. d. Organ. **11**:383, 1901; **20**:187, 1905.

to irregular resorption within the canal and replacement of the old haversian system by newly deposited lamellae. As a result of resorption, the reconstruction does not produce the identical pattern of the bone but the result is a disordered reconstruction, with numerous irregular haversian systems and parts of systems of all sizes known as breccie. In adult human bone, there are few undisturbed haversian systems, especially as compared with animals. In the bones of the lower jaw and those of the hand and skull, the regularly formed haversian systems are even fewer in number than in the other bones.

The Ground Lamellae.—The compacta or cortex of the tubular bone of man consists, for the greatest part, of haversian systems. On the outer and inner surfaces of the compacta, there is often but not always a system of lamellae running parallel to these surfaces but not related to central blood vessels. These are the ground lamellae. The outer ground lamellae are under the periosteum, by which they are deposited on the haversian columns of the compacta. Since these are formed during the active growth of the bone, it sometimes happens that haversian systems formed later are enclosed in ground lamellae. Inner ground lamellae are present only in the diaphysis of long bones and run in the same general direction as do the outer ground lamellae. They are present in the diaphysis only when there is no spongy bone, that is, when the marrow is in contact with the compacta. These lamellae are deposited from the endosteum. The thickness of the outer and inner ground lamellae varies considerably in different tubular bones and may measure anywhere from 45 to 900 microns. Where the superficial or outer ground lamellae are best developed, some may be present between the haversian systems and may be called interstitial ground lamellae. If such ground lamellae are present, they must not be confused with the interstitial lamellae resulting from the breaking up of haversian systems. The interstitial ground lamellae may be differentiated from the interstitial lamellae that result from the breaking up of haversian systems by the fact that the former contain a few Sharpey fibers, while the latter do not.

The thickness of an individual ground lamella is about like that of an haversian lamella, and the number of ground lamellae varies between 10 and 100. The fine fibrils of the ground lamellae run like those in the haversian lamellae, but the direction of the fibrils may change within the same lamella. The ground lamellae are perforated transversely by Sharpey fibers.

The Interstitial Lamellae.—The interstitial lamellae must not be confused with the haversian lamellae when old haversian systems break. Their formation may be followed by studying cross-sections of compact bone. Existing haversian systems are being constantly resorbed on

the inner or vessel side and replaced by new haversian columns. The junction or line of demarcation of the resorption is represented in section by a shiny and irregular line. If the rate of new bone formation exceeds that of resorption, the old haversian system, that is, the system that is being replaced, splits up, and the fragments of the splintered haversian system fill the spaces between the haversian systems, producing the interstitial lamellae which are also called breccie. The haversian interstitial lamellae form an important supporting mass for the haversian columns of the compacta and nearly always run diagonally. These lamellae are of the same thickness as the haversian lamellae, and the fibrils retain the same appearance and course as existed in the haversian systems from which they formed. In the cortex of adult bone, in addition to the interstitial lamellae, small nests of typical coarse-fibered bone with some bone cells have occasionally been described.

The Cement Lines.—The haversian systems and fragments of haversian systems are separated from each other and from the ground lamellae by sharply defined lines. These were designated as cement lines by von Ebner, the term by which they are now known. These lines are generally quite irregular, though some may be straight. In general, they represent the site of resorption of lamellar bone, and on their surface, facing the haversian canal, new lamellar bone has been deposited. On an average, a cement line is thinner than a lamella, but it may be about as thick as a lamella. The cement lines are nonfibrillar (figs. 11 and 12). Von Ebner found that in the immediate vicinity of the cement lines new formed bone showed no lamellar structure but was made up of fibrils and irregularly distributed cells. This is best seen in the buckled regions of the cement lines, for where the cement lines are straight the lamellae are preserved. Von Ebner noticed that some bone cells lie on the border of the cement lines, which seem to cut them and their processes. He noticed also that the canaliculi of the bone cells in the region of the cement lines do not traverse them but turn away. This was confirmed by Matschinsky.[13] Schaffer expressed the belief that while most of the canaliculi and bone cells in the region of the cement lines do not traverse them, some actually do and these communicate with the cells of the adjacent haversian systems. Weidenreich believed that anastomoses through the cement lines between the cells of different haversian systems exist, and are important in the transformation and growth of the formed bone. While preparations that my associates and I have made confirm the observations of von

13. Matschinsky: Ueber das normale Wachstum der Roehrenknochen des Menschen Arch. f. mikr. Anat. **39**:151, 1892.

Ebner, we found a few canaliculi which traversed the cement lines, as described by Schaffer.

The cement lines divide the bone into innumerable irregular islands of tissue. The union of these pieces at the cement lines is not as firm as the union of two individual lamellae through the medium of the fibrils and is dependent mainly on the interlocking of the adjacent pieces. In a specimen of macerated bone that had been exposed to the elements for a long time, we found that the lamellae held together very

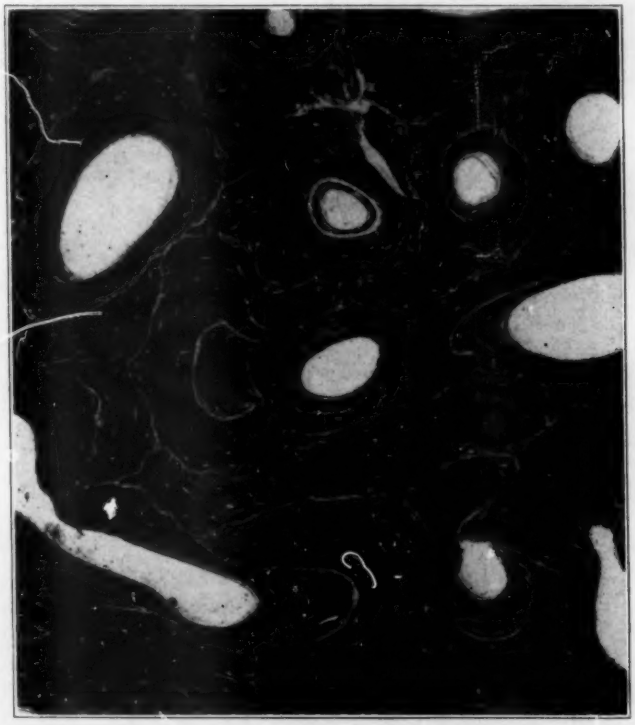

Fig. 11.—Section through diaphysis of human bone from a case of osteomyelitis. The white lines are the cement lines and illustrate how the cortex is composed of innumerable irregular pieces cemented together. Frozen section stained by Bielschowsky's silver metho..

well, but that the haversian systems separated from each other at the cement lines.

In illustration 226 of his "Handbuch der Gewebelehre," Koelliker demonstrated lines found regularly between the periosteal ground lamellae, though they varied in number and thickness. These lines contain no fibrillae of their own; in this respect, they are similar to the cement lines, but differ from them in that Sharpey fibers penetrate them. These lines contain bone cells and canaliculi or may be penetrated by

these structures. They are formed by a deposition of calcareous material in an interfibrillar cement substance and are therefore analogous to cement lines in structure. These lines are formed because bone is deposited underneath the periosteum rhythmically, and between two such lines one can determine the amount of growth that has occurred during a certain period. In the inner ground lamellae of a metacarpal bone, many such lines were found.

Sharpey Fibers.—Sharpey fibers were described under coarse-fibered or primary bone, and they were shown to constitute an important part of this bone. They were described as being present in periosteally formed bone, and being derived from the periosteum. In fine-fibered or lamellar bone, they are few. Sharpey described them as

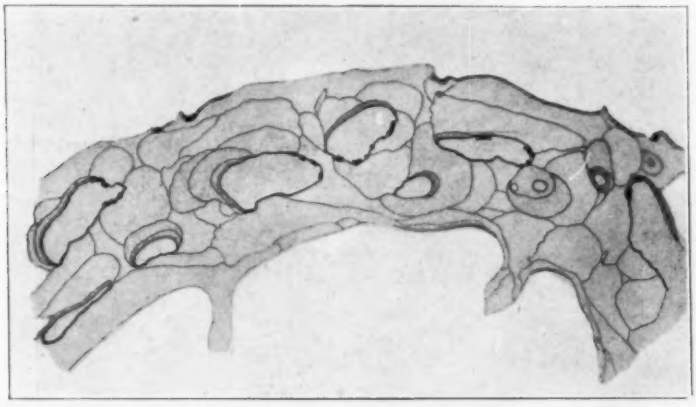

Fig. 12.—Diagrammatic representation of a cross-section of the shaft of a phalanx of a child, aged 6 years, showing the reconstructional changes going on, and the division of the cortex into innumerable pieces cemented together. After Burkhardt and Petersen.

fibers or fiber bundles which perforate the lamellae, passing through them in a perpendicular or more or less oblique direction. These perforating fibers may be seen with the aid of the microscope in a thin transverse slice of a decalcified cylindric or cranial bone when the ground lamellae are pulled apart. In this way some lamellae will be observed with fibrous processes attached to them which vary in length and usually taper and are pointed at the free extremities but sometimes are abruptly truncated. These fibers have obviously been drawn out from the adjacent lamellae through several of which they must have penetrated. Sometimes, indeed, indications of perforation may be recognized in the part of the section of bone from which the fibers have been pulled out. The processes in question are viewed in profile but they may frequently be seen on the flat surface of detached lamellae, pro-

jecting like nails driven perpendicularly or slantingly through a board, while other lamellae present obvious apertures of considerable size through which perforating fibers have passed. These fibers may also be demonstrated by staining methods. They may be demonstrated in animals like adult guinea-pigs, in which the ground lamellae are well developed, by teasing apart the outer ground lamellae in a thick frozen section.

While some experimenters have been unable to find Sharpey fibers in adult human bone, and this is probably due to the fact that in such bone, ground lamellae may be few or absent, Koelliker and Weidenreich claimed to have demonstrated them in small numbers in subjects up to 60 years of age. In adult bone, Weidenreich and Koelliker found them only in the outer ground lamellae which are derived from the periosteum, and they showed variation in quantity and thickness. According to von Ebner, they appear infrequently in the haversian systems of adult bone. Braus [14] described and illustrated them as occurring in all lamellae, but this is denied by almost all other workers. Weidenreich believed that Sharpey fibers end abruptly at the cement lines. They are estimated as 3 mm. in length in adult human bone. They are believed to prevent the displacement of the ground lamellae. As they pass through the lamellae they sometimes branch, and these branches are directed toward the surface of the bone. They may be quite thick, and nests of these fibers may sometimes occupy a large area in the ground lamellae, and they may have a few bone cells embedded in them. They may then simulate an ossified tendon insertion.

Elastic Fibers.—Von Ebner and Koelliker believed that elastic fibers are found, though seldom, in outer ground lamellae, and according to them some Sharpey fibers are elastic fibers. Von Ebner also described elastic fibers in the innermost lamellae of the haversian system and believed that these fibers were found only in adults. Weidenreich found many elastic fibers in the outer zone of the periosteum, a few in coarse-fibered bone, but none in lamellar bone. On the other hand, Maier [15] and Tafani [16] believed all Sharpey fibers to be elastic fibers. However, the consensus of opinion is that there are few elastic fibers in bone. While some elastic fibers mingle with the Sharpey fibers, others are independent of these fibers, and may accompany the vessels of the cortex.

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14. Braus: Anatomie des Menschen, 1 Bewegungsapparat, Berlin, Julius Springer, 1921, p. 835.

15. Maier: Die elastischen Fasern des Knochens, Virchows Arch. f. path. Anat. **26**:358, 1863.

16. Tafani: Le tissu des os, les fibres perforantes ou de Sharpey, Arch. ital. di biol. **8**:66, 1887.

THE SPONGIOSA

Origin.—Spongy bone makes up most of the mass of the smaller bones like those of the tarsus, carpus, the bodies of the vertebrae and ribs, and the upper and lower ends of tubular bones. While considerable literature exists under the title of spongy bone, most of this literature deals with the question of the influence of the mechanical factors of stress and strain on the architecture of spongy bone, rather than with the question of origin, reconstruction and relation of this bone to the compacta. Furthermore, there has crept into the literature the erroneous statement that all spongy bone is formed from the inner surface of the cortex by a peeling off process, in the course of which cortical haversian

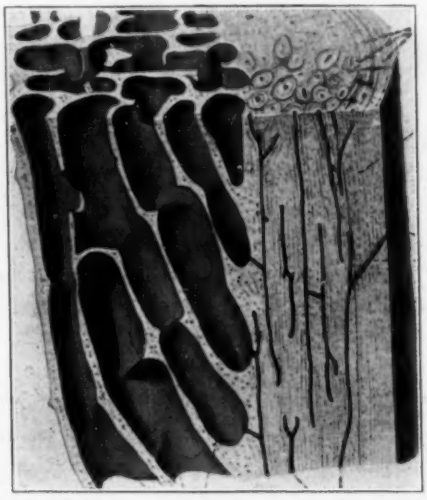

Fig. 13.—Diagrammatic representation of a longitudinal view of a bone, showing both compacta and spongiosa. The cortex on the right shows the outer ground lamellae, with some Sharpey fibers penetrating them. The haversian systems are illustrated, and the longitudinally directed haversian canals are shown. The spongy trabeculae and lamellae are illustrated in the left half of the picture. After Braus.

systems have been widened through resorption by osteoclasts from within the haversian canals. This conception has arisen as a result of the observation, particularly in the upper end of the femur, that some spongy trabeculae are attached at their base to the inside of the compacta. That some spongy trabeculae arise in this way, particularly in the diaphysis, there is no doubt, but in general this conception is wrong.

Structure.—On close inspection, adult spongy bone is found to be composed of slender bars or spicules or thin lamellae of bone which meet and join in a reticular manner, producing an open structure which has been compared to lattice work (figs. 13 and 14). In this way con-

siderable strength is attained without undue weight, and it may usually be observed that the strongest laminae run through the structure in those directions in which the bone naturally has to sustain the greatest pressure. The open spaces or alveoli of the bony network communicate freely. In the fresh state, they contain marrow and blood vessels and give support to these structures.

Due to the variety of the forms of the components of spongy bone, they have been designated by many names. Roux [17] divided the components of spongy bone as follows; (1) tubes (tubuli), (2) hemispherical spaces (pilae), (3) plates (lamellae) and (4) beams (trabeculae). The tubuli ossei are the long spaces in spongy bone enclosed by the thicker trabeculae, and the pilae ossei are curved spaces in spongy

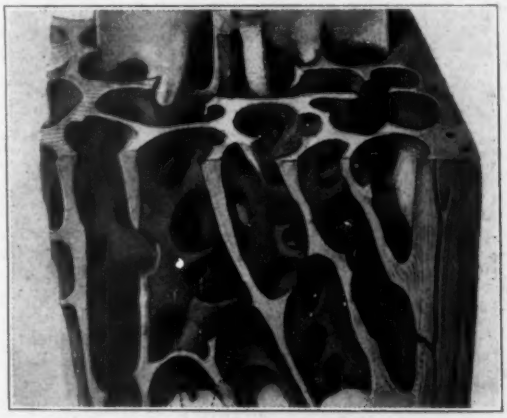

Fig. 14.—A large and more detailed diagrammatic representation of the spongy bone, shown in figure 13. The construction of the trabeculae is plainly seen at the upper surface of the drawing and the surfaces of the lamellae are also seen. The tubuli between the lamellae are represented. The apertures in the lamellae by which the tubuli connect are shown. After Braus.

bone, particularly underneath the articular cartilage and are enclosed by the thinner lamellae. Where the trabeculae or thin lamellae cross each other, a netlike spongy bone is produced. This division of the elements of spongy bone is a rough evaluation, because there are innumerable transition forms and shapes which make a strict terminology impossible. The lamellae and trabeculae of the spongy bone show numerous fine apertures. The marrow spaces which are separated by the trabeculae or lamellae communicate with each other through the apertures. In places the apertures show a regular arrangement, forming pairs of openings placed above each other. The flat surface of the lamella then

17. Roux: Die Entwicklungsmechanik, Vortr. u. Aufs. u. Entwcklngsmech. d. Organ., 1905, nos. 1 to 5.

appears as a strainer. Sometimes larger holes are present, and the face of the lamella appears latticelike.

When the end of the diaphysis of a long bone is examined, it is seen that the cortex becomes thinner from the point where spongy bone appears in considerable amounts. This thinning of the cortex does not necessarily occur uniformly throughout the same horizontal plane of the bone. As was pointed out, the belief is that the cortex thins out because it gives rise to the spongy lamellae, but it must again be emphasized that all the spongy lamellae certainly do not arise from the cortex and that in the epiphyseal ends of the bone the cortex is always thin or inconsequential and the spongy bone is considerable. The appearance

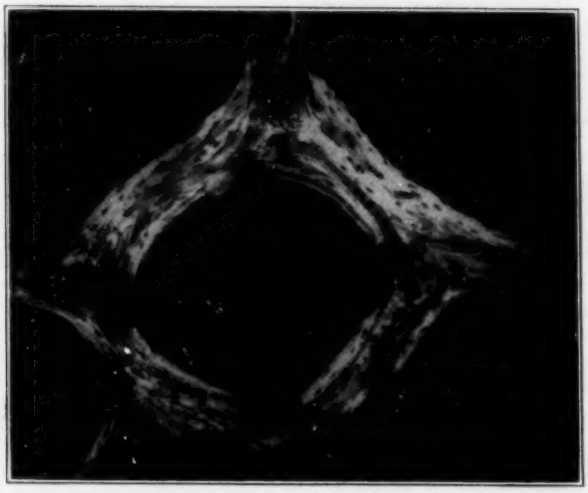

Fig. 15.—Details of structure of a lamella of spongy bone in a ground disk examined with polarized light.

of laminae of bone arising from the cortex is due rather to the spongy lamellae and trabeculae fusing with the cortex.

The spongy trabeculae and lamellae differ from the haversian systems in that only the larger trabeculae contain blood vessels, and compared with the cortex the vessels are few. When trabeculae contain blood vessels, they are surrounded by concentric lamellae. The inner part of a spongy trabecula is composed of small pieces, the breccie, on which layers of lamellar bone are deposited. These breccie consist of small, angular pieces of lamellar bone and are similar to the interstitial lamellae. The lamellae, of which the breccie are comprised, frequently run diagonally to the lamellae on the surface of the trabeculae, and in one trabecula several breccie may be seen, each directed at a different angle. The outer surface of the trabeculae is composed of lamellae which are laid down somewhat concentrically around the marrow spaces.

A few osteoblasts line the trabeculae of adult bone. The trabeculae contain bone cells which anastomose with each other. The fibrillar structure of the trabeculae is no different from that in the lamellar systems. However, the details of the fibrillar arrangement in spongy bone seem not to have been widely investigated. The active cellular bone marrow is supported in the meshes between the spongy bone; and in the diaphysis of long bones of adults, in which the spongy trabeculae are few or entirely absent, the marrow is fatty (fig. 15).

THE RELATION OF FUNCTION TO THE STRUCTURE OF BONE; WOLFF'S LAW

When the spongy lamellae and trabeculae in the neck of the femur are examined, they are seen to course in archiform effect from one inner wall of the bone to the opposite wall. They cross each other at nearly right angles, and their points of intersection lie nearer that cortex from which the lamellae seem to be separating at the more acute angle. The spongy lamellae and trabeculae as they seem to come off from the cortex make more acute angles the further up they are in the shaft. However, in other bones, like the vertebrae, while the spongy lamellae and trabeculae cross each other to form spaces, there is no particular arrangement of the spongy bone such as occurs in the upper end of the femur.

On the basis of the appearance of the spongy bone in the upper end of the femur, there has been developed the theory of the transformation of bone due to mechanical influences exerted on it. The inner architecture of the spongy bone in this region, that is, the direction and contour of its trabeculae, is supposed to be conditioned by external stresses and strains exerted on the bone. In spite of the large literature and the immense amount of work that has been done on this subject, there is still much difference of opinion as to the proper interpretation of the inner structure of the femur.

The Origin of the Conception of Wolff's Law.—Those who maintain the view that bone is transformed by mechanical influences exerted on it base their beliefs on the observations that the mechanical structure of the normal femur conforms closely to the mathematical proportions of a structure of similar shape and physical properties, the Fairbairn crane, which is designed to resist the action of loads similar in amount and manner of application to those sustained by the human femur. This led to the conclusion that the details of the inner structure of the femur are based on exact mathematical laws, and further, that the form of bone is adapted to its functions.

It is argued that if the external form and inner architecture of a normal bone represent the adaptation to normal function, then alterations in the mechanical demands made on normal bones should be

followed by corresponding changes in both the internal and the external structure. Such changes should produce a deformity, a marked change in contour, or a displacement from the natural normal position. Such changes of contour or displacement from the normal position are regarded as a physiologic adaptation of the structure to pathologic mechanical conditions, and therefore to pathologic function. The doctrine of the functional form of bone, with its corollary of the functional pathogenesis of deformity, has been ably set forth by Julius Wolff, but before him the problem of the mechanics of the inner structure of bone was much discussed. The history of the subject is well reviewed in the monographs of Wolff [18] and Albert [19] and in the more recent American paper by Koch.[20] The foundation on which this doctrine rests is the correspondence between the inner structure of the upper end of the femur and the lines of stress in the Fairbairn crane. The analysis of the crane was made by the mathematician, Culmann, who observed that the cancelli of many bones were arranged in forms similar to those which he had computed as the lines of maximum internal stress in a Fairbairn crane having a form which was assumed to approximate that of the upper fourth of the femur. The conclusion was that the cancelli lie along the paths of maximum internal stress and thus transmit a maximum load in the bone with a minimum of material. This observation of Culmann is the mathematical basis of the modern theory of the functional form of bone, and this theory has been criticized on purely mathematical grounds.

The Law.—In 1892, Wolff developed his theory of the relation of the internal structure of bone to function and dealt with the transformation of bone in normal and pathologic cases and discussed in considerable detail the structural changes in bone due to changed mechanical conditions. This work is abundantly illustrated with examples of many rare deformities, taken from collections in the principal museums of Germany. Culmann's mathematical analysis of the lines of stress in the Fairbairn crane and the somewhat analogous direction of the trabeculae in the upper femur are cited by Wolff as mathematical proofs that the architecture of the spongy bone of the neck of the femur follows exact mathematical laws, and that the form and inner structure of bone are determined by the mechanical conditions present.

Recently, Koch published an exhaustive study on the laws of bone architecture. His paper was directed toward bringing definite mathematical proof of the law. He arrived at the same conclusions as Wolff

18. Wolff: Das Gesetz der Transformation der Knochen, 1892.

19. Albert: Einfuehrung in das Studium der Architektur der Roehrenknochen, Wien., 1900.

20. Koch: Laws of Bone Architecture, Am. J. Anat. **21**:177, 1917.

did, that the normal external form and internal architecture of the human femur result from an adaptation of form to the normal mechanical demands on, or normal function of, this bone. He stated that the proportions of the femur are everywhere such as to show a definite mathematical relationship between the body weight and the internal structure of the bone; there is a definite relation between the structure and the stress at every point. According to him, spongy bone is homogeneous with compact bone as a structural material and differs from it mechanically only in possessing less strength, which is approximately in proportion to its density as compared with compact bone.

The general law of bone, the adaptation of form to function, holds true mathematically and mechanically in the normal human femur, and therefore, Koch concluded, for all other normal human bones. According to him a foundation is laid for the study and mechanical analysis of the spongy bone entering into the structure of other parts of the skeleton, by the application of the principle that spongy bone and compact bone are homogeneous materials and differ chiefly in strength, approximately in proportion to their densities. The thickness and closeness of spacing of trabeculae in bone vary directly with the intensity of the stresses transmitted by them.

This theory of the functional forms of bone with that of the functional pathogenesis of deformity has been accepted by many surgeons and orthopedists as a working basis in the treatment of deformities, but it has been the subject of so much controversy that much confusion has arisen as to the value of the theory in everyday practice.

Objections to the Law.—Wolff's doctrines of the functional form of bone and the functional pathogenesis of deformity have been vigorously assailed on various grounds by many investigators. Even those who have partly accepted the Wolff-Roux conceptions still feel that in addition to mechanical factors which influence the form and structure of bone, phylogenetic and developmental factors are at work. Even Gebhardt, who was a pupil of Roux, admitted that there are other than mechanical factors influencing the structure of bone. Von Recklinghausen,[21] although in the main agreeing with the mechanical view, expressed himself as believing that the mechanical views are not sufficient to explain the internal architecture of bone entirely. Friedlaender [22] laid most stress on the direction of the vessels in determining the internal architecture of bone. He also stated that much more significance must be attached to the factors of development. Triepel [23]

21. Von Recklingshausen: Normale und pathologische Architekturen der Knochen, Deutsche med. Wchnschr. **19**:506, 1893.

22. Friedlaender: Beitrag zur Kenntnis der Architektur spongiöser Knochen, Anat. Hefte **23**:235, 1904.

23. Triepel: Die Architektur der Knochenspongiosa in neuer Auffassung, Ztschr. f. d. ges. Anat., part 2; Ztschr. f. Konstitutionslehre **8**:269, 1922.

would also minimize the importance of the mechanical factors. Petersen [24] objected to the theory of Wolff and Roux on the grounds that the calculated direction of the main tension lines of the neck of the femur is not applicable to the bone, since these calculations, obtained from the Fairbairn crane, apply to homogeneous substances with the same elastic properties throughout. But bone is not homogeneous. It is made up of innumerable small pieces which are cemented together and which vary in size and number depending on the internal reconstruction which is always going on. According to Petersen, the determining factor in the structure of bone is functional activity which stimulates bone reconstruction through its effect on the cells, but function does not directly produce the internal structure by exerting a direct mechanical effect on the bone and thus causing the trabeculae and laminae to arrange themselves along certain lines of tension.

Most surgeons have more or less accepted the dicta of Wolff, but most anatomists and embryologists, while agreeing that mechanical factors may influence the inner structure of bone, are of the belief that the phylogenetic and hereditary factors are important, if not most important. It seems to me that this is the most logical point of view. Even if the trabeculae of the head of the femur were arranged in a way to conform with the mathematical principles as applied in the Fairbairn crane, nevertheless this fact could not be explained solely on mechanical grounds because the developmental influence could not be disregarded. In favor of this view is the fact that the trabeculae of all femurs are arranged in practically the same way, irrespective of mechanical influences exerted on them. Also every tissue constructs itself according to a certain pattern, and even in regeneration the original pattern is reconstructed. This is seen in the regeneration of a transplant, as of the thymus, which when placed in the abdominal wall reproduces thymic lobules with cortex and medulla. All tissues have an innate architectural pattern which they produce but which may be influenced by factors like nutrition, function and environment. And so I must agree with those who believe that the mechanical factors, though important, are only secondary in influencing the internal architecture of bone.

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24. Petersen: Ueber Methoden zum Studium des Knochens, Ztschr. f. wissensch. Mikr. **43**:355, 1926.

SURGERY OF THE ESOPHAGUS *

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Surgical procedures have been employed for the relief of several pathologic conditions in the esophagus, the most common being the impaction of foreign bodies, cardiospasm, benign cicatricial stricture, carcinoma and diverticula. Impacted foreign bodies are now much less commonly dealt with by surgical means because of the easier and less dangerous method, in the hands of experts, of extraction through the esophagoscope, while surgical procedures have been almost eliminated from the treatment for cardiospasm. In this article the last three conditions, essentially, are considered.

Until within the past fifty years the esophagus received scant attention from the surgeon in spite of the well recognized pathologic conditions for which, theoretically, surgical procedures might well have been indicated. This is all the more striking when one remembers that the ancient Hindoos operated on the bladder for stone, and that Herophilus of the Alexandrian School used the knife boldly on such internal organs as the liver and spleen. For many years the only operative procedure attempted on the esophagus was esophagotomy of its cervical part. This was followed by the more complicated and drastic plastic operations and resections. The latter have so far been attended by a depressing mortality, so that some of the most stout-hearted surgeons often prefer to leave the anatomic relations of the viscus undisturbed rather than bring about almost certain death by surgical intervention. It is well known that when Billroth began to popularize his gastric operations he did so at the cost of many lives; yet nothing is more gratifying than the results of surgical methods in this sphere today. Moynihan [1] and Balfour [2] recently each reported a large series of

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* An abridgment of the thesis awarded the Heath Scholarship of the University of Durham, 1928. The experimental work was done at the Division of Experimental Surgery and Pathology, The Mayo Foundation, under the direction of Dr. F. C. Mann. It is realized that this article falls far short of being a comprehensive survey of the subject, and for more complete works the reader is referred to such books on thoracic surgery as those of Ferdinand Sauerbruch (Die Chirurgie der Brustorgane, Berlin, Julius Springer, 1925, vol. 2) and Howard Lilienthal (Thoracic Surgery, Philadelphia, W. B. Saunders Company, 1925, vol. 1), or to the recent monograph of Victor von Hacker and G. Lotheissen (Chirurgie der Speiseröhre, Neue Deutsche Chir. **34**:569, 1926).

1. Moynihan, Berkeley: Two Lectures on Gastric and Duodenal Ulcer: A Record of Ten Years' Experience, Bristol, John Wright & Sons, 1923, 48 pp.

2. Balfour, D. C.: Fundamental Principles in Surgery of the Stomach and Duodenum: Report of 400 Cases, Surg. Gynec. Obst. **42**:167, 1926.

operations on the stomach with a mortality ranging from 1 to 2 per cent. Thus, by dint of perseverance and improvement in technic from time to time, that which was once a great risk has been converted into a safe every-day occurrence. This is not so in regard to esophageal surgery. The results of operative work in this sphere have been disappointing on the whole, in spite of modern advances in asepsis and technic. Esophagotomy can be performed fairly safely and diverticula can be removed without much risk, but carcinoma still claims its victims, operation in most cases serving only to hasten death. Still, some of those skilled in thoracic surgery, such as Torek, Meyer, Eggers and Lilienthal, have hopes that the time is not far distant when the surgeon will be able to wage war successfully against it. In his Hunterian Lecture, Abel [3] took the same optimistic view.

Two facts stand out prominently in a consideration of surgery of the esophagus: (1) its comparatively recent history and (2) its slow and unsatisfactory progress. The undoubted cause of the first fact seems to be the relative inaccessibility of the esophagus, the viscus being deeply seated throughout its entire course. At first it took courage to make the deep dissection of the neck necessary for its exposure and surgical treatment. When this had been achieved it was probably thought impossible to expose the thoracic portion because of its intimate relations with such viscera as the pleura, lungs and aorta, injury to any of which must always be regarded with grave concern. For some time attempts were not made to lay bare the esophagus in its thoracic bed. Then came the development of the technic of posterior mediastinotomy whereby the esophagus could be reached without entrance to the pleural cavity. Later still, the invention of the differential-pressure chamber, by overcoming the well recognized occurrence of fatal postoperative pneumothorax, opened the road to the esophagus through the pleural cavity. Today it may be said that the surgeon's initial difficulty with regard to the esophagus, namely, that of overcoming its inaccessibility, has been solved. At least thus far has surgery of the esophagus progressed.

Although, as I have mentioned, the less severe operations of esophagotomy and extirpation of diverticula can usually be successfully performed, one seeks for explanations of why the more extensive operations, with a few exceptions, have been failures. Here one must remember that the final aim of the surgeon is to overcome carcinoma. Resection is therefore essential, and it is in the treatment of the esophagus after resection has been carried out that most of the difficulties which are at present preventing the progress of surgery in this sphere have arisen and still remain.

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3. Abel, A. L.: The Treatment of Cancer of the Oesophagus, Brit. J. Surg. **14**:131, 1926.

Theoretically, the operation of resection with end-to-end anastomosis is feasible; however, several factors exist to add to its risk and difficulty. At the present time, carcinoma of the esophagus is not diagnosed early enough. In most cases it would seem that this is due to the delay on the part of the patient in consulting a surgeon, but some patients with a very short history on examination are found to be suffering from extensive carcinoma. In either case, by the time the diagnosis is made the growth has invaded the esophageal wall to such an extent that the amount of the viscus to be removed in order to extirpate the carcinoma widely enough is much greater than that which would allow the cut ends to be brought together and sutured.

Assuming that a carcinoma is of such dimensions that when extirpated the cut ends of the esophagus can be brought together without undue tension, what other difficulties are there to overcome? The esophagus differs from the bowel in that it does not possess a serous covering. The significance of this is apparent. When the bowel is sutured, the peritoneum, in response to the traumatic irritation imposed on it, throws out lymph which coagulates, thereby sealing the line of suture. The surgeon does not get natural help of this sort from the esophagus, and consequently the safety of the suture of this viscus is greatly impaired. It is the general opinion that apart from the absence of help from serosa, the wall of the esophagus forms poor material for suture, both submucous and muscular coats being easily cut through. In this connection, Miller and Andrus found that if the lower third of a freshly removed human esophagus is divided and then joined by two layers of fine silk sutures grasping the submucosa, the artificial juncture withstands the pressure of a column of water 6 feet (182.9 cm.) high without the escape of either gas or fluid. From this investigation it is clear that the esophageal wall has the required strength, but the important point to be remembered is that in the living body its strength is dependent entirely on a sufficient blood supply.

Unfortunately, the esophagus is poorly supplied with blood although this is derived from several arteries, the aorta, inferior thyroids, subclavians, left inferior phrenic and left gastric. The great danger in end-to-end anastomosis of the esophagus is constriction of the blood vessels by the sutures, which is only too often the cause of necrosis with perforation of its wall and consequent leakage of its contents, resulting in fatal infection of the mediastinum or cellular planes of the neck. The loosening of the esophagus in its bed previous to resection, by necessitating severance of some of its blood vessels, will have already considerably diminished the nutrition of its cut ends, sometimes to such a degree that necrosis and gangrene ensue apart from any further diminution by constriction with sutures.

The outer coat of the esophagus consists of connective tissue continuous with that of the structures surrounding it. Carcinoma will usually be found to have invaded this and to have fixed the viscus. The loosening of the growth involves an opening of the cellular planes of the neck or the connective tissues of the mediastinum, and a grave risk is thereby incurred, because of the danger of ensuing cellulitis or mediastinitis which may take place in spite of the most careful aseptic precautions. This risk is always present, even when the esophagus is only loosened in its bed; however, if the lumen is opened, the risk increases considerably because of the highly infective nature of the esophageal secretion.

Coincident with the danger of mediastinitis is that of infection of the pleura, and the remarks concerning the former apply with equal force to the latter.

If the carcinoma extends through the esophageal wall the vagi are always involved and usually cannot be separated; they must be cut if resection is to be carried out. Although severance of these nerves does not always produce any apparent detrimental results, it is possible, and even probable, as Meyer pointed out, that interference with them plays a great part in bringing about the state of shock which has so many times proved fatal.

Lastly, the presence of the diaphragm has added considerably to the technical difficulties of operations on the lower end of the esophagus from the standpoint of resection of this part of the viscus and its substitution by stomach or intestine.

The chief reasons for the late inception of surgery of the esophagus, its relatively slow progress and its lack of attendant success can be summarized as follows:

1. The inaccessibility of the viscus; this applies particularly to the thoracic portion where its surgical approach is intimately bound up with previously developed operative procedures on the pleural cavity.

2. The absence of a serous coat in its cervical and thoracic parts.

3. A poor blood supply, interference with which often results in necrosis with tearing of sutures and extravasation of infective mucous secretion.

4. The danger of postoperative infection, cervical cellulitis, mediastinitis, pleurisy and empyema.

5. The probable danger of great shock resulting from interference with the vagi.

6. The presence of the diaphragm.

DEVELOPMENT OF ESOPHAGEAL SURGERY

The literature on surgery of the esophagus shows the great ingenuity that has been displayed by surgeons in their attempt to effect cures of the various pathologic conditions.

The earliest operations were essentially those of cervical esophagotomy, the simplest operation possible on the esophagus performed in its most accessible part for the extraction of foreign bodies. Thus, the first surgical measures were in the nature of emergency operations. Goursauld,[4] in 1738, appears to have been the first surgeon to perform this operation. It was not found mentioned again until nearly a century afterward when Rolland,[5] in 1819, performed it successfully. In 1833, Arnott,[6] of the Middlesex Hospital, was the first Englishman to perform esophagotomy. The patient died fifty-six hours after the operation. Arnott remarked that he could not find any record of the operation having been done in England up to the time of his own attempt. In 1858, Cock[7] said: "I can find but very few cases recorded in which the pharynx and esophagus have been opened for the purpose of extracting a foreign body." He himself successfully performed esophagotomy on a man who had swallowed a tooth plate.

In 1868, Cheever[8] reported two successful cases and reviewed the literature on esophagotomy up to that time. He reviewed twenty-three other cases; however, the issue had not been successful in all. His list of surgeons contained the well known names of Syme and Nélaton, the latter being of the opinion that the operation was one of the gravest and most difficult in surgery.

The usual method employed for exposing the cervical esophagus and removing a foreign body was as follows: A left lateral incision was made along the inner border of the sternomastoid muscle from the level of the upper margin of the thyroid cartilage downward for about 10 cm., with incision through skin, platysma and deep fascia. If the anterior jugular vein was encountered, it was cut between ligatures. The omohyoid muscle was then either cut or retracted and the hyoid depressor muscles retracted medially while the sternomastoid was drawn laterally. The esophagus was found between the thyroid gland medially and the carotid sheath laterally and was incised longitudinally over the foreign body as far posteriorly as possible so as to lessen the risk of injury to the recurrent laryngeal nerve. The foreign body was then extracted and the esophageal wound closed with interrupted sutures or left open, the former practice being the more usual.

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4. Goursauld, quoted by Cheever: Two Cases of Esophagotomy for the Removal of Foreign Bodies, ed. 2, Boston, J. Campbell, 1868.

5. Rolland, quoted by Cheever: Two Cases of Esophagotomy for the Removal of Foreign Bodies, ed. 2, Boston, J. Campbell, 1868.

6. Arnott, J. R.: Case of Oesophagotomy, Tr. Med. Chir., London **18**:86, 1833.

7. Cock, Edward: A Case of Pharyngotomy for the Extraction of a Foreign Body, with Some Remarks, Guy's Hosp. Rep. **4**:217, 1858.

8. Cheever, D. W.: Two cases of Esophagotomy for the Removal of Foreign Bodies, with Some Remarks, ed. 2, Boston, J. Campbell, 1868.

There are a few points with regard to this operation which appeared in the literature at that time and which are worthy of note. There was a controversy as to the relative merits of a median and a lateral incision. The advocates of the former, among whom was Nélaton, preferred the median line with splitting of the thyroid cartilage so as to avoid injury to the recurrent laryngeal nerves. Those who recommended the lateral incision declared that with care these nerves could be avoided easily and that the exposure they obtained was superior to that obtained by their opponents. Whether or not a swelling appeared in the side of the neck after the impaction of a foreign body in the esophagus was given considerable attention. Several surgeons went so far as to say that the absence of swelling was a contraindication to operation. Again the advisability of ensuring drainage in case of leakage of secretion through the wound in the esophageal wall was well recognized.

At this time an attempt had not been made to expose the thoracic portion of the esophagus, and the only hope of extracting a foreign body impacted in that portion lay in being able to reach it from above through cervical esophagotomy or from below through gastrotomy. In 1886, because of this Richardson [9] made some observations on the accessibility of foreign bodies fixed in this part of the esophagus. In experiments on cadavers he found that a finger introduced into the esophagus through a low incision in the neck could easily be brought into contact with a finger inserted upward through the stomach. As a result, he asserted that there was not a part of the esophagus which might not be reached with the finger either by gastrotomy below or by esophagotomy above. He also showed the easy distensibility of the cardia which allowed the introduction of two fingers up through it simultaneously, a distinct advantage to the operator attempting to free an impacted foreign body. These observations were of considerable practical value at that time. Since then the advent of the esophagoscope has dispensed almost entirely with the necessity of the extraction of impacted foreign bodies by the external route, because the danger entailed by the latter procedure is usually regarded as greater than that by the former.

As time went on it was only natural that surgeons should begin to devise ways and means of laying bare the thoracic part of the esophagus. It was natural, too, that an extrapleural route should be chosen because of the well recognized danger of pneumothorax resulting from opening of the pleural cavity.

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9. Richardson, M. L.: A Case of Gastrostomy, Digital Exploration of the Esophagus and Removal of Plate of Teeth: Recovery, Boston M. & S. J. **115**:567, 1886; The Possibility of Operations on the Esophagus Through the Stomach as Shown by Dissections, Lancet **2**:707, 1887.

In 1888, Nasiloff [10] working on the cadaver, resected from three to six ribs posteriorly, and through a vertical incision close to the vertebral column pushed forward the pleura, stripped it off the esophagus and thus exposed this structure extrapleurally. This is the first record in the literature of posterior mediastinotomy; the operation was a distinct advance not only in surgery of the esophagus but in thoracic surgery.

Quénu and Hartmann,[11] in 1891, and Potârcă,[12] in 1894, demonstrated subperiosteal resection of portions of the second to the sixth ribs on the cadaver, entering the posterior mediastinum and exposing the esophagus. They hoped that by this method of approach the resection of carcinoma of the esophagus would be feasible.

In 1895, Bryant [13] devised another method of approach to the mediastinal portion of the esophagus. Instead of a straight vertical incision like that of Nasiloff,[10] Quénu and Hartmann,[11] and Potârcă,[12] he made a quadrilateral flap with its base at the spinal column. The flap included all tissues down to the ribs and when it was raised from the underlying structures it was reflected medially. Three ribs were exposed and the middle one was resected for a length equal to that of the flap. The ribs above and below were divided only and turned medially with the intervening intercostal structures, forming a flap with its hinge near the vertebral column. After this the operation was carried on after the manner of Nasiloff and the esophagus exposed. Bryant demonstrated his method on the cadaver.

Rehn,[14] in 1898, was apparently the first to employ a modification of Bryant's operation on the living subject. He made a large muscle flap with its base extending from the third to the ninth spinous process and then resected several ribs (an osteomuscular flap as devised by Bryant was not used). In the first operation he wounded the pleura; pneumothorax developed and the patient died six weeks after operation. In the second operation, the exposure of the carcinoma was satisfactorily carried out but the lesion was definitely inoperable. Suppuration of the wound and death on the sixth day followed. The esophagus was approached from the right side in both cases.

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10. Nasiloff, J. J.: Oesophagotomia et resectio eosophagi endothoracica, St. Petersburg, Vrach, 1888, vol. 9, p. 481.

11. Quénu and Hartmann: Des voies de pénétration chirurgicale dans le médiastin postérieur, Bull. et mém. Soc. de chir. de Paris **17**:82, 1891.

12. Potârcă, I.: L'oesophagotomie intrathoracique par le médiastin postérieur, Roumanie Med. **2**:116, 1894.

13. Bryant, J. D.: The Surgical Technique of Entry to the Posterior Mediastinum, Tr. Am. Surg. A. **13**:443, 1895.

14. Rehn: Operationen an dem Brustabschmitt der Speiseröhre, Verhandl. d. deutsch. Gesellsch. f. Chir. **27**:448, 1898.

Llobet,[15] in 1900, was the first to perform Nasiloff's operation on a human being, the case being one of benign stricture of the esophagus. Following a left paravertebral vertical incision and resection of several ribs, he pushed forward the pleura and exposed the esophagus without difficulty. There were two strictures which he incised longitudinally and then inserted a soft sound through the nose down into the stomach so as to model the lumen of the esophagus. The patient died eight days after operation. Purulent empyema was found at necropsy and was attributed to infection of the pleural cavity by the regurgitated gastric contents. Llobet called attention to the fact that he could have reached the esophagus in this position (just below the aortic arch) much better from the right side. He considered the operation feasible.

In 1901, Enderlen [16] using the flap method, operated on a patient for the removal of a tooth plate in the thoracic portion of the esophagus. He extracted the plate successfully but in doing so injured the edges of the esophageal wound so severely that he decided not to suture but to drain. The patient was nourished through a previously made gastrostomy opening and although he was not well enough to be dismissed from observation until nine months after the operation, he recovered. Enderlen advised that the approach to the thoracic portion of the esophagus above the bifurcation of the trachea be made from the left side.

Henle,[17] like Enderlen, performed posterior mediastinotomy for the removal of a foreign body in the esophagus. The patient died nine days after operation. In 1903, Faure [18] and Tuffier [19] exposed the esophagus by the posterior mediastinal route, but the patients died. Tuffier mentioned the transpleural route for exposure of the esophagus but believed that the danger from pneumothorax and pleural infection was almost too great.

By this time posterior mediastinotomy as an approach to the thoracic portion of the esophagus had become a recognized surgical procedure. There thus remain two approaches to be considered: the anterior mediastinal and the transpleural. The former is mentioned merely to be condemned. In Cairo in 1897, Milton [20] split the manubrium and body

15. Llobet, A. F.: L'opération de Nassilov: La première intervention à Buenos Aires, Rev. de chir. **21**:674, 1900.

16. Enderlen: Ein Beitrag zur Chirurgie des hinteren Mediastinum, Deutsche Ztschr. f. Chir. **61**:441, 1901.

17. Henle, quoted by Lilienthal: Ann. Surg. **74**:259, 1921; ibid. **76**:333, 1922.

18. Faure, J. L.: Cancer de la portion thoracique de l'oesophage. Extirpation du néoplasme, par la voie mediastinale postérieure droite, combinée à une incision cervicale, Bull. et mém. Soc. de chir. de Paris **29**:122, 1903.

19. Tuffier: Sur la résection de l'oesophage thoracique, Presse méd. **11**:364, 1903.

20. Milton, H.: Mediastinal Surgery, Lancet **1**:872, 1897.

of the sternum longitudinally in the median line and was able to pull the two halves about 6 cm. apart. This operation was undertaken for the removal of tuberculous lymph nodes, and it is easy to see that this procedure or any of its modifications as a means of reaching the esophagus extrapleurally is decidedly impracticable and well nigh impossible, because of the numerous important structures which lie in the way. Apart from this, the exposure of the esophagus, once it was obtained, would not be nearly so good as by the other two routes.

An Italian surgeon, Biondie,[21] in 1895, was the first to attempt to explore the esophagus by the transpleural route; he used the dog as his subject. He employed a paravertebral incision followed by resection of two or three ribs. The pleura was incised, the pleural cavity opened, and the esophagus exposed by incision of the parietal pleura.

The opening of the pleural cavity for the intrathoracic operation on the esophagus or any other of the thoracic viscera was not put on a safe basis, however, until the invention of the differential-pressure chamber by Sauerbruch [22] and the positive-pressure apparatus by Brauer and Petersen [23] in 1904. These inventions, by preventing collapse of the lung during operation and pneumothorax afterward, gave a great impetus to intrathoracic surgery, including that of the esophagus. They have been replaced largely by the simple method of intratracheal insufflation introduced by Meltzer and Auer [24] in 1909.

Now that the dangers of opening the pleural cavity have been overcome to such an extent that the surgeon need not hesitate to operate in it, there remains only the question of the type of incision to employ in order to get the required exposure. Dobromysslow, for example, used the flap method with subperiosteal resection of the underlying ribs. Sauerbruch introduced the simple intercostal incision of skin, muscles and pleura. This he found eminently suitable for experimental work on dogs, and it is still the most commonly used for that purpose. The usual procedure for opening the pleural cavity in man now includes either the division of ribs or their resection. Torek, in his famous case, cut down to the ribs through a curved incision, the anterior part of which was over the seventh intercostal space while the posterior part turned vertically upward near the vertebral column. He then divided the seventh, sixth and fifth ribs just lateral to their tubercles, and the

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21. Biondie, D.: Esophago-gastrostomia sperimentale intratoracica, Policlinico (suppl.) 1895, p. 964.

22. Sauerbruch, Ferdinand: Ueber die Ausschaltung der schädlichen Wirkung des Pneumothorax bei intrathorakalen Operationen, Zentralbl. f. Chir. **31**:146, 1904.

23. Brauer and Petersen: Ueber eine wesentliche Vereinfachung der künstlichen Atmung nach Sauerbruch, Ztschr. f. physiol. Chem. **41**:299, 1904.

24. Meltzer, S. J., and Auer, John: Continuous Respiration Without Respiratory Movements, J. Exper. Med. **11**:622, 1909.

pleural incision ran parallel to that in the skin. By retraction excellent exposure of the middle part of the pleural cavity was obtained and the esophagus easily reached. The level of the incision was planned according to the part to be explored.

The exposure of the posterior mediastinum for the laying bare of the thoracic portion of the esophagus extrapleurally has also received attention as time has gone on, and Lilienthal's [25] recent method, a modification of that employed by Torek, gives excellent exposure. His incision starts 20 or 22.5 cm. from the spine at whatever level he chooses and runs backward along a rib to the edge of the longitudinal spinal muscles and then curves upward parallel to the spine for four or five intercostal spaces. The rib over which the incision is made is resected subperiosteally, and the rib below and two or three above are divided just lateral to their tubercles. The usual care is taken in the ligation of intercostal vessels and the separation of the pleura from the periosteum of the ribs and intercostal muscles. By the introduction and spreading of a rib retractor, these ribs, which have been divided, are easily "shingled," one on top of the other, and thus exposure is obtained.

Grégoire's [26] extrapleural and extraperitoneal method of exposing the lower thoracic and cardiac segments of the esophagus is interesting and might well be mentioned. A U-shaped incision with unequal limbs is made on the left side of the thorax. It starts behind at the level of the eighth rib near the spine and runs vertically downward over the necks of the ribs until it reaches the twelfth where it curves forward along that rib for about 10 cm.; then it turns upward in the posterior axillary line to the level of the eighth rib. A musculocutaneous flap is raised, the twelfth rib resected, the eleventh sectioned at each end of its exposed part and the tenth cut only through its neck. The arteries in the corresponding intercostal spaces are ligated and cut and a large osteomuscular flap can then be raised, exposing the pleura and below this the diaphragm. The pleura is pushed forward off the vertebral column, aorta, esophagus and diaphragm. After the diaphragm is bared, it is split close to the neck of the twelfth rib near the esophageal orifice, and here the left inferior phrenic artery must be ligated before it is cut as its ends are likely to retract. After being split the diaphragm is retracted with the pleura and good exposure of the lower end of the esophagus is obtained.

For operations on the esophagus by the posterior mediastinal route, the side by which the better exposure is obtained still remains a matter

25. Lilienthal, Howard: Posterior Mediastinotomy, Arch. Surg. **6**:274 (Jan.) 1923.

26. Grégoire, Raymond: Voie d'accès sur le segment cardio-eosophage permettant d'éviter la plévre et le péritoine. (Voie thoraco-abdominale extra-séreuse), J. de chir. **21**:673, 1923.

of the choice of the individual surgeon; most are agreed that the right side is better for operations in the region of the hilum and that the lower part of the thoracic portion of the esophagus is better approached from the left.

From the foregoing brief outline of the development of surgery of the esophagus, it can be seen that the viscus has become accessible throughout the whole length of the course. In the thorax two routes are available, the extrapleural and the transpleural. The abdominal part of the esophagus can be exposed through either the abdominal or the thoracic route.

LESIONS OF THE ESOPHAGUS

All lesions in the esophagus have a tendency to cause narrowing of the lumen, thus producing obstruction with its attendant symptoms. The esophagus, like any of the other hollow viscera in the body, may be obstructed by causes: (1) in the lumen, such as foreign bodies and tumors (polypi); (2) in the wall itself, such as cardiospasm, congenital stricture or stricture resulting chiefly from fibrosis in injury, inflammation or new growths—tumors, apart from fibrosis, may lead to narrowing—and (3) outside the wall, such as tumors, diverticula, aneurysms, enlarged lymph nodes and abscesses.

Treatment, whether or not it is surgical, is always directed toward relief from the obstruction. With regard to impacted foreign bodies, it is noticed that their removal has passed largely from the domain of surgery since the advent of the esophagoscope. Should operation be the only available means of relief, however, it would consist in exposure of the esophagus at the site of impaction and longitudinal incision through the wall over the foreign body followed by extraction with as little resultant trauma as possible. The edges of the esophageal wound would then be brought together, usually with two rows of sutures, the second inverting the first. Drainage must be provided for. Should the impacted foreign body be situated in the cardiac or lower thoracic part of the esophagus, it might be possible to extract it through a gastrotomy wound by digital manipulation and so avoid the risk entailed of opening the esophagus.

As mentioned, operation has been almost eliminated from the treatment for cardiospasm, and its place has been taken by the more conservative treatment of dilatation.

The stricture resulting from fibrosis following injury or inflammation (benign cicatricial stricture), when believed to be impermeable, has been treated by the plastic formation of an artificial esophagus which circumvents the stricture and reestablishes continuity between the mouth and stomach. In order that the surgical treatment of a carcinomatous stricture may be successful, resection of the growth itself is essential. Although subsequent end-to-end anastomosis may be attempted, it is

more usual to bridge the gap caused by the resection by some plastic procedure. Hence two series of operations for the relief of stricture have been attempted: esophagoplastic operation alone and resection with or without a plastic operation.

ESOPHAGOPLASTIC OPERATIONS

The types of plastic operations devised for the relief of benign cicatricial strictures which are believed to be impermeable, having as their object the formation of an artificial esophagus, have been many and various, and no tissue or viscus that would seem suitable has been neglected. Thus, skin, fascia, stomach and large and small intestines have all been used. Before the introduction of these operations, patients were usually subjected to gastrostomy, and there surgical treatment ended. Gastrostomy as a temporary measure is helpful, but as a permanent one it has many drawbacks and may become a veritable nuisance, particularly for a working man. The patient's food must always be specially prepared; the skin around the gastrostomy opening often becomes ulcerated and difficult to keep clean, and, what is even more exasperating to the patient, nothing has been done which will restore to him the joy of taking food by mouth and the power of deglutition for which he seems to crave and without which life seems to be intolerable. In spite of this unfortunate state to which gastrostomy may lead, many surgeons regard it with favor and publish statements to the effect that their patients are well satisfied with the results. Another fact which must be given just consideration is the youth of most of the patients suffering from benign stricture of the esophagus (many of them are actually children); to provide them only with a gastrostomy opening will limit their enjoyment of social intercourse and activity, and probably seriously jeopardize their chances of success in life. The realization of these drawbacks to gastrostomy was the factor which led to the introduction of esophagoplasty.

It may take months to complete the plastic operations, and the futility, as well as the lack of justification, of performing them in cases of carcinomatous stricture without primary resection of the growth itself has long been recognized. I shall describe the various types of esophagoplastic operations.

Skin.—In 1894, H. Bircher attempted extrathoracic esophagoplasty for carcinomatous stricture, using the skin of the anterior wall of the thorax and the neck. The first step was to make two vertical parallel incisions about from 7 to 8 cm. apart, slightly to the left of the median line and extending from the submaxillary region to the margin of the rib. The edges of the strip of skin were turned forward and brought together in the median line by interrupted sutures so that a tube lined by epidermis was formed. The edges of the skin of the incision on

both sides were undermined for 1 or 2 cm., pulled together and sutured over the tube of skin already formed. About six weeks later a gastrostomy opening was made and its edges connected with those of the lower opening of the tube of skin. Nine days later fluid nourishment was poured through the tube from above and it entered the stomach without trouble. Three days later the patient died of pulmonary embolism. At necropsy it was found that the sutures of the tube had given way in some places. The second patient died from pneumonia, and Bircher found that the anterior part of the tube of skin had separated for about 4 cm. and that from this opening the lumina of both stomach and tube could easily be reached. Bircher had intended to make a juncture between the upper end of the tube with the cervical part of the esophagus. He stated that although fluid food passed down the artificial esophagus with ease, he did not believe that solid food would, owing to the absence of peristalsis in the tube. Although Bircher's attempts to form a new esophagus were made in 1894, they were not published until 1907, by E. Bircher.[27] This procedure and its modifications, which seem to be the safest of all the methods devised for esophagoplasty, curiously enough seem to have been forsaken for a long time through the introduction of other much longer and more dangerous procedures, and have found favor again only during the last few years.

Payr,[28] in 1917, seems to have been the first to complete successfully Bircher's technic; the patient was a young man, aged 20.

In 1917, Esser [29] devised an ingenious method of forming a tube of skin to act as a new esophagus. He considered that in the formation of a tube according to Bircher's method there was likely to be too much tension on the skin and he found a method of avoiding this factor. He first performed a Witzel operation for gastrostomy. Then he made a transverse incision about 4 cm. long through the skin of the anterior wall of the thorax midway between the jugular notch and the gastrostomy opening slightly to the left of the sternum. After entrance to the subcutaneous tissues through the incision with a suitable instrument, he undermined the skin upward and outward to the level of the thyroid gland and downward to the gastrostomy opening. The thickest instrument was from 2.5 to 3 cm. in diameter. He then proceeded to line the tunnel with Thiersch skin grafts, so that when these had taken he

27. Bircher, Eugen: Ein Beitrag zur plastichen Bildung eines neuen Oesophagus, Zentralbl. f. chir. **34**:1479, 1907.

28. Payr: Fälle von antethorakalen Oesophagoplastik, München. med. Wchnschr. **64**:783, 1917.

29. Esser, J. F. S.: Sogennante total Oesophagoplastik aus Hautlappen nach Thiersch ohne Verwendung von Darmschlinge, Deutsche Ztschr. f. Chir. **142**:403, 1917.

had a tube lined by skin and formed in such a manner as to avoid tension. The technic of applying the grafts to the inside of the subcutaneous tunnel is interesting. He split a rubber drainage tube longitudinally and painted it with albumin (white of egg); when this was dry, he laid on it the Thiersch grafts, wound side outward, and turned the edges of the grafts into the longitudinal slit. The adhesion of the Thiersch grafts to the tube by the medium of the egg-white enabled the tube to be introduced into the tunnel with the grafts in position. Two graft-covered tubes were inserted, one into the upper part of the tunnel, the other into the lower part. Their approximated ends were connected by a core made of sterile wood. After ten days, the rubber tubes were removed and the upper and lower parts of the skin tube united by suture. In his first case, Esser had considerable difficulty in uniting the cervical portion of the esophagus with the upper end of the tube of skin because of the high position of the stricture and the consequent short length of the oral end of the esophagus. He managed, however, by closing the defect with skin flaps. He effected the juncture of the gastrostomy opening and the lower end of the tube of skin by constructing a sac from the abdominal wall to surround both orifices. The sac was made in the same way as the Bircher tube of skin. By this method a valvelike arrangement was made whereby he hoped to prevent the regurgitation of gastric contents (with their deleterious effects on the Thiersch grafts) into the skin tube, for the sac would have to become filled first and in filling would compress the anterior wall of the lower end of the skin tube against the posterior wall and so close the orifice. His first case was successful and at the time of writing he had begun a second case but had completed only the formation of the tube of skin by his Thiersch graft method.

In 1921, Fonio [30] suggested that the lower end of the tube of skin be joined directly to the wall of the stomach, the mucosa being sutured to the lower edge of the tube of skin followed by serous sutures inverting the wall of the stomach, as in a Senn gastrostomy. The soft tissues, then the skin, would be brought together and sutured over the anastomosis of the stomach and tube of skin.

Realizing the advantage of a seroserous suture, Galpern,[31] in 1925, sought to remedy this defect in the lower end of the skin tube by the use of omentum. He first made a transverse incision in the skin about 8 cm. long, midway between the xiphoid and the umbilicus, and undermined the skin above it, making a subcutaneous pocket from 5 to 6 cm. long. In this he placed omentum, which was extracted from

30. Fonio, A.: Ein Fall von antethorakalen Oesophagoplastik, Schweiz. med. Wchnschr. **51**:865, 1921.

31. Galpern, E. J.: Eine neue Methode der Oesophagoplastik, Zentralbl. f. Chir. **52**:182, 1925.

the abdomen. A week later, he made a tube of skin according to the method of Bircher, the lower edge being formed by the transverse incision, so that the lower 4 or 5 cm. was surrounded with omentum which had grown together with the subcutaneous tissues. In this way Galpern provided a serosal covering for the lower part of the skin tube, to which the stomach might then be united. He experimented on rabbits and dogs. In the former, all experiments were failures because the skin covering the pocket became mummified and unsuitable for the formation of a skin tube. By his experiments on dogs he was able to convince himself that the omentum grows together with the subcutaneous tissue and will take part in an anastomosis as serosa. He expressed the belief that heterogeneous omentum procured during laparotomy, for example, can be used with greater facility and with equally good results. His experiments were not completed when he made his report.

In 1922, von Engelbrecht [32] reported a case of a girl, aged 15, on whom he performed anterior esophagoplasty for impermeable stricture. He successfully completed the artificial esophagus, although he had some trouble with the formation of fistula at the juncture of the skin tube and the esophagus above the gastrostomy opening and skin tube below.

In 1925, Rovsing [33] described a method which appeared to be a modification of that introduced by Bircher with which Rovsing appears to have been unfamiliar. Juncture of the lower end of the skin tube and the gastrostomy opening is effected in a manner similar to that in which Esser made the sac, except that the amount of skin used is just sufficient to form a tube continuous with the lower end of the skin tube above and surrounding the gastrostomy orifice below. An interesting modification which Rovsing introduced lay in his treatment of the aboral end of the esophagus after its division in the neck. Instead of closing it, which is the usual practice, he brought it out through a small incision in the left supraclavicular fossa, fixed it to the skin with silk and drained it with a tight rubber drain. In this way he avoided the possibility of mediastinitis which might ensue from the inefficient closure of the aboral end or from the giving way of the closing sutures because of tension resulting from secretion accumulating above the stricture. At this time he reported two successful cases, and in 1926, this number had increased to four, with a fifth which was incomplete.[34] Two of the patients were boys aged 5 and 9 years.

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32. Von Engelbrecht, H.: Beitrag zur antethorakalen Oesophagoplastik, Beitr. z. klin. Chir. **126**:278, 1922.

33. Rovsing, Thorkild: Antethoracic Oesophagoplasty: A New Method, Ann. Surg. **81**:52, 1925.

34. Rovsing, Thorkild: The Technique of My Method of Antethoracic Oesophagoplasty, Surg. Gynec. Obst. **43**:781, 1926.

In 1926, Braizew [35] completed esophagoplasty on a girl, aged 12, by means of skin, although the procedure occupied nearly a year and necessitated many operations. His technic differed from the technics described in that he avoided the juncture of the skin tube with the gastrostomy opening by making a second opening in the stomach near the cardia. This allowed the temporary use of the first opening for feeding purposes and also reduced the length of the skin tube. The second opening was made by drawing up a cone of stomach into the abdominal wound and surrounding it with crossed muscle strips from the rectus abdominis, thus forming a sphincter. The functional result was good, the patient being able to swallow any kind of food.

Anterior Wall of the Stomach.—In 1901, Depage [36] by devising a new method of gastrostomy, paved the way for the later real esophagoplastic operations. He used a vertical flap from the anterior wall of the stomach with its base upward and close to the lesser curvature. By closing the stomach with a continuous suture and continuing this on to the upturned flap, he converted the latter into a tube which he found could be drawn upward through a parietal tunnel almost to the xiphoid process. In 1903,[37] he reported having used the method in six cases with satisfactory functional results.

In 1911, Hirsch [38] employed the same method but with the intention of replacing the lower part of the esophagus by the tube formed by the suturing of the edges of the flap. He made the longitudinal axis of the flap parallel to that of the stomach with the base toward the fundus, in this way ensuring a good blood supply from the branches of the left gastric and short gastric arteries. The lower end of the tube was fixed to the peritoneum to avoid kinking, and the tube itself was brought up onto the thorax subcutaneously. Jankovskis [39] quoted E. Hesse as having performed the Hirsch operation four times with two successful results. This is the only instance noted in the literature of the use of this operation on man. Jankovskis also pointed out that its disadvantage lies in the fact that the stomach considerably diminishes in size in cases of impermeable esophageal stricture.

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35. Braizew, W. R.: Zur Frage der antethorakalen Dermato-Oesophagoplastik, Zentralbl. f. Chir. **53**:2010, 1926.

36. Depage, A.: Nouveau procédé pour la gastrostomie, J. de chir. et Ann. Soc. Belge de chir. **1**:715, 1901.

37. Depage, M.: Nouvelle méthode de gastrostomie, abstr. Presse méd. **19**:755, 1903.

38. Hirsch, Maximilian: Plasticher Ersatz des Oesophagus aus dem Magen, Zentralbl. f. Chir. **38**:1561, 1911.

39. Jankovskis, J.: L'oesophagoplastie totale; ses résultats functionelles, J de chir. **25**:633, 1925.

Greater Curvature of the Stomach.—In 1905, Beck[40] started to improve gastrostomy by the formation of a plastic tube from the greater curvature of the stomach, with its base to the left, thus ensuring a good blood supply by means of the left gastro-epiploic artery. He cut a flap, and, by a continuation of the suture which closed the stomach on to the edges of the flap, brought them together and so formed a tube. Starting first with a small flap, he gradually extended the operation until most of the greater curvature was included in the flap. He then found that the tube was of such length that it could be brought upward on the surface of the thorax far enough to be united to the cervical portion of the esophagus. By measurements on the cadaver, he came to the conclusion that the operation was feasible on the human being. His experiments, which were briefly recorded in a journal of limited distribution, were not spread abroad in the general medical literature, and, consequently, the credit of having devised this form of esophagoplasty has mostly gone to Jianu,[41] who, in 1912, apparently in ignorance of Beck's work, published similar experiments on dogs and on the cadaver and advised the use of the method for benign stricture in the human subject. After the formation of the tube, its base is sutured to the peritoneum in the upper part of the abdominal wound. A vertical median line incision is made in the skin of the thorax and the edges undermined. The tube is then drawn upward, laid in this subcutaneous path and the edges of skin sutured together over it. The edges of the end of the tube are sutured to those of a transverse incision at the upper end of the vertical one. Later, anastomosis can be made between the oral end of the transversely cut cervical portion of the esophagus and the upper end of the tube made from the greater curvatures.

Röpke,[42] in 1921, was the first to use the Beck-Jianu type of esophagoplasty in operating on the human being. He performed the operation on a man with carcinoma of the esophagus, but did not do a resection. Instead of making a subcutaneous pathway for the artificial esophagus as did Jianu,[41] he tunneled below the pectoral muscles. The gastric contents did not regurgitate. The case was successful apart from the fact that the carcinoma was not resected.

In 1913, Meyer[43] published a report of three cases in which the Beck-Jianu method of operation was successful. The first case was

40. Beck, Carl: Demonstration of Specimens Illustrating a Method of Formation of a Prethoracic Esophagus, Illinois M. J. **7**:463, 1905; Plastic Operations on the Stomach: An Experimental Study, Surg. Gynec. Obst. **20**:170, 1915.

41. Jianu, Amza: Gastrostomie und Oesophagoplastik, Deutsche Ztschr. f. Chir. **118**:383, 1912.

42. Röpke, W.: Ein neues Verfahren für die Gastrostomie und Oesophagoplastik, Zentralbl. f. Chir. **39**:1569, 1912.

43. Meyer, Willy: Oesophagoplasty, Ann. Surg. **58**:289, 1913.

complicated by gangrene of the seromuscular coat of the uppermost extremity of the new esophagus. He believed this was due to the constricting action of the through-and-through sutures on the vessels, and formed the opinion that the mucosa alone should be sutured to the borders of the skin wound. In this case, Meyer had followed Röpke's method of leading the new esophagus through a subpectoral tunnel. Submuscular suppuration and perichondritis ensued. In his other two cases, he used Huelte's wire-stitching instrument for the closure of the longitudinal incision in the stomach; it has the great advantage that the stomach is not even opened. Meyer preferred the subcutaneous rather than the subpectoral placing of the Beck-Jianu tube because local infection is easier to deal with, and there is less risk of its spreading to the ribs or sternum. In another publication, Meyer [44] advised the intrathoracic use of the Beck-Jianu tube to replace the lower portion of an esophagus that had been resected for carcinoma.

In 1914, Jianu [45] reported the cases of the first two patients treated by this method. Both were cases of benign stricture, and the results were successful. He stated that it was feasible to perform the operation not only on a normal stomach, but also on one which might be adherent to the abdominal wall, as after gastrostomy.

In 1913, Enderlen and Hotz [46] reported their experimental work on esophagoplasty. They stated that their efforts to substitute a loop of small bowel or a Beck-Jianu tube for the esophagus uniformly resulted in gangrene, and that the mobilization of the proximal portion of the cervical esophagus resulted in failure because of necrosis of its end.

In 1919, Nicolaysen [47] published the report of an interesting case. A few years previously the patient had undergone a Wullstein and Roux [48] type of operation for esophageal stricture. The jejunal loop had necrosed, the operation thus being a failure. Nicolaysen then operated by the Beck-Jianu method, completing the new esophagus by a tube of skin. Complete success rewarded his efforts.

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44. Meyer, Willy: Ein Vorschlag bezüglich der Gastrostomie und Oesophagoplastik nach Jianu-Röpke, Zentralbl. f. Chir. **40**:267, 1913.

45. Jianu, Amza: Ueber Oesophagoplastik, Deutsche Ztschr. f. Chir. **131**:397, 1914.

46. Enderlen and Hotz: Experimente zur Oesophaguschirurgie, Zentralbl. f. Chir. **40**:1175, 1913.

47. Nicolaysen, John: Ein Fall von gelungener Oesophagusplastik, Zentralbl. f. Chir. **46**:922, 1919.

48. Wullstein, L.: Ueber antethorakale Oesophago-Jejunostomie und Operationen nach gleichem Prinzip, Deutsche med. Wchnschr. **30**:734, 1904. Roux: L'oesophago-jéjunogastrostomose, nouvelle opération pour rétrécissement infranchissable de l'esophage, Semaine méd. **27**:37, 1907.

In 1922, Lotheissen [49] reported four cases in which successful operations were performed by this method. In two of them the cervical portion of the esophagus was united directly with the Beck-Jianu tube, while in the remaining two this juncture had to be effected by the interposition of a tube of skin about 10 cm. long. In one of the latter cases, regurgitation of gastric contents caused erosion of the skin tube so that many minor plastic operations had to be performed for repair, the outcome finally being successful.

In 1926, Grigorjev [50] in a plastic operation, made a tube from the greater curvature of the stomach, constructed in such a manner as to open into the stomach near the pylorus, in this respect differing from the Beck-Jianu tube. It was brought up to the clavicle without tension. The functional result was poor: fluids would not pass into the stomach through the tube, and if introduced through a stomach tube, they regurgitated into the new esophagus. This was thought to be due to the resistance of the pyloric sphincter; a plastic operation was performed on this structure, but there was no improvement in function. The patient died after four months. Grigorjev considered this operation unsuitable and recommended the Wullstein-Roux type of esophagoplasty.

Whole Stomach (Antiperistaltic).—In 1913, von Fink [51] devised a method of operating on a patient who had a carcinoma of the cardia and lower end of the esophagus. At operation he found the cardia forming a stiff funnel and adherent to the liver. He mobilized the remainder of the stomach and first part of the duodenum, cut through the juncture of the first and second parts of the duodenum and closed the distal end. He then brought up the stomach over the left margin of the ribs onto the anterior thoracic wall subcutaneously, although the extent to which he did this was naturally limited by the fixation of the cardia. The opening of the duodenum reached to about the level of the nipple. Posterior gastro-enterostomy was then performed. Later, the cervical portion of the esophagus was united to the duodenal opening. After a few days, blood-stained fluid flowed from the abdominal wound. The fluid increased in amount, and the patient became weaker and died. By this operation von Fink established in his own mind the usefulness of the stomach and duodenum as material for esophagoplasty.

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49. Lotheissen, G.: Zur Behandlung der Speiseröhrenstrikturen, Zentralbl. f. Chir. **40**:1969, 1913; Ueber plastischen Ersatz der Speiseröhre insbesondere aus dem Magen, Beitr. z. klin. Chir. **126**:490, 1922.

50. Grigorjev, A.: Bildung einer künstlichen Speiseröhre nach Halpern, abstr. Zentralorg. f. d. ges. Chir. **37**:104, 1927.

51. Von Fink, Franz: Ueber plastischen Ersatz der Speiseröhre, Zentralbl. f. Chir. **40**:545, 1913.

Whole Stomach (Isoperistaltic).—In 1920, Kirschner [52] introduced a new method of esophagoplasty, in which, like von Fink,[51] he used the whole stomach. After ligating and dividing the left gastric, left gastro-epiploic and short gastric arteries, he mobilized the whole stomach by cutting through the gastrocolic and gastrohepatic ligaments. He then cut through the stomach about 4 cm. below the cardia and, after making an anastomosis between the cardiac stump and the jejunum, he drew up the stomach subcutaneously, cardiac end first, in front of the wall of the chest. He thus arranged the stomach in an isoperistaltic way, because he feared the effect of antiperistalsis which might cause trouble in the von Fink type of operation. Later, the cervical portion of the esophagus was to be anastomosed to the cardiac end of the stomach. Kirschner reported one case in which the operation was completed with a successful result, which, however, took twenty-seven months to attain, the chief difficulty being the contraction of the cervical esophagostomy opening, which required many minor plastic operations. His second patient lived only a month, and died from abscess of the lung. At necropsy an ulcer was found in the displaced stomach at the level of the third rib; it had perforated into the pectoralis major muscle.

In 1921, Kümmell [53] performed esophagoplasty, using Kirschner's method in three cases of impermeable stenosis due to cardiospasm, benign stricture and inoperable carcinoma, respectively. All three patients died soon after the operation. In two of them, Kümmell did not anastomose the cardiac end of the esophagus with the small intestine. In each of them, the accumulation of secretion above the closing ligature resulted in rupture with peritonitis. At necropsy, there were no signs of impairment of nutrition of the wall of the stomach in any of the cases.

In regard to the mobilization of the stomach, the work of Miller and Andrus,[54] in 1923, is of importance. They found that in nineteen dogs in which the left gastric and short gastric arteries, as well as the anastomotic branches from the phrenic arteries near the cardia were ligated, only one showed any alteration in the viability of the stomach; a definite necrosis of a limited portion of the fundus took place. On the other hand, if one goes a step further and divides the left gastro-epiploic artery (as Kirschner did), one finds that in dogs at least two thirds of the stomachs so treated show an area of necrosis on the

52. Kirschner: Ein neues Verfahren der Oesophagoplastik, Arch. f. klin. Chir. **114**:606, 1920.

53. Kümmell, Hermann: Zur Operation des Kardiospasmus und des Oesophaguscarcinoms, Arch. f. klin. Chir. **117**:193, 1921.

54. Miller, R. T., Jr., and Andrus, W. D. W.: Experimental Surgery of the Thoracic Esophagus, Bull. Johns Hopkins Hosp. **34**:109, 1923.

fundus from 3 to 4 cm. in diameter, involving the entire thickness of the wall and resulting in acute perforating ulcer. Such a lesion was found in Kirschner's [52] second case. In view of their experience, Miller and Andrus considered Kirschner's method of mobilizing the stomach a risky procedure.

In 1926, Wajgiel,[55] working on dogs and cadavers, made injections into the stomachs after the ligation of the left gastric, short gastric and left gastro-epiploic arteries. He found that the fundus of a stomach, the blood supply of which had been treated in this manner, was not filled with the injection mass. This corroborates the observations of Miller and Andrus.

Jejunum.—Wullstein,[56] in 1904, was the first to utilize the jejunum for esophagoplastic work; he performed his experiments on the cadaver. He resected about 15 cm. of jejunum taken from the intestine a short distance (about 30 cm.) below the duodenojejunal flexure. After the reestablishment of the continuity of the bowel by end-to-end or lateral anastomosis, he pulled up the resected jejunal loop with its attached mesentery through the transverse mesocolon and greater omentum and anastomosed the aboral end to the anterior surface of the stomach. The oral end of the loop was then drawn up onto the anterior thoracic wall and sutured to the thoracic musculature along the left border of the sternum; over the loop of intestine so fixed he sutured the skin flap made with its base to the left prior to the opening of the peritoneal cavity. The anterior circumference of the end of the jejunal loop was sutured to the skin laid over it. The next step was to make a tube of skin in a similar manner to that of Bircher and to join it below to the upper end of the jejunum and above to the oral end of the divided cervical portion of the esophagus.

In 1907, Roux [57] performed his famous successful operation of esophagojejunogastrostomy on a child suffering from intractable benign esophageal stricture. In reality this was a modification of Wullstein's method. His results with gastrostomy in benign stricture had been poor, and he decided to attempt to form a new esophagus with the aid of the small intestine. He took the jejunum because of the regularities of the arteries supplying it and the ease with which they are recognized. He first resected a loop of the upper portion of the jejunum of a length calculated to reach almost to the pharynx. Toward its oral end he ligated and cut the vascular stems of the arcades and then divided the mesentery.

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55. Wajgiel, Eugenjusz: Experimentelle Untersuchungen über die Gefässversorgung des Magens insbesondere mit Rücksicht auf die Operation der vollständige Oesophagoplastik nach Kirschner, abstr. Zentralorg. f. d. ges. Chir. **36**:34, 1926-1927.

56. Wullstein (footnote 48, first reference).

57. Roux (footnote 48, second reference).

At its aboral end, he conserved the mesentery containing one or more arterial stems, and thus obtained a length of intestine supplied with blood through its mesenteric pedicle. Then followed the reestablishment of the continuity of the intestine by a button for intestinal anastomosis. The resected loop was drawn up in front of the transverse colon and the aboral end implanted in the stomach close to the lesser curvature, care being taken not to compress the transverse colon. By means of Richelot forceps, Roux undermined the skin of the thorax just to the left of the sternum as far upward as the manubrium, where they came out through a transverse incision. By opening the forceps and giving them a to-and-fro movement, he made a tunnel through which the jejunum was easily drawn, and the circumference of the end of the loop was sutured to the edges of the wound in the skin. The peritoneum was closed. After the wounds had healed, the subcutaneous intestinal loop could be seen to contract actively at intervals. Roux was later going to join the cervical portion of the esophagus to the upper end of the jejunal loop and so complete that which he set out to do.

Thus, to Roux belongs the credit of proving the feasibility of making a new esophagus from the intestine in human beings. It infused new enthusiasm into the minds of many who had hitherto believed such surgical success to be impossible, and this was reflected in the increased number of case reports of attempted esophagoplasty which began to appear in the literature. Judging from the literature, of all types of esophagoplasty the Wullstein-Roux method has proved the most popular. The juncture of the cervical portion of the esophagus with the jejunal loop sometimes is direct as devised by Roux, and sometimes by skin esophagoplasty according to Wullstein.

In 1908, Herzen [58] performed a Roux operation on a patient with carcinoma. Death followed sixteen days afterward. Herzen was not satisfied with Roux's technic and sought to change it somewhat, the chief modification being the passing of the jejunal loop through the transverse mesocolon and gastrocolic omentum so as to shorten it and to avoid the possibility of compression of the transverse colon. Later, he completed the operation in two cases with success. The first was that of a man with carcinoma of the esophagus, who was shown at the Seventh Russian Surgical Congress, at which time he enjoyed good health. The other was that of a girl, aged 20, who had stricture which resulted from swallowing sulphuric acid. Herzen mentioned that in this case intestinal peristalsis showed itself in the jejunal loop after each new mouthful of food. His modification of shortening the path of the jejunal loop by passing it through slits in the transverse mesocolon and

58. Herzen, P.: Eine Modification der Rouxischen Oesophagojejunogastrostomie, Zentralbl. f. Chir. **35**:219, 1908.

gastrocolic omentum had already been suggested by Wullstein in 1904. In 1908, Wullstein [59] drew attention to the similarity of his method to that of Bircher and Roux.

In 1911, Lexer [60] performed a Roux operation for carcinoma of the esophagus. Gangrene of the subcutaneous loop of intestine ensued. He performed the Wullstein operation in another case with success. Lexer, watching this case, made the important observation that the absence of peristalsis in the section containing the skin tube of the artificial esophagus did not have an adverse effect on the ingestion of food. Thus, Bircher's doubts as to the ability of such an esophagus to allow the passage of solid food were settled. It was a most interesting observation from the physiologic standpoint as it proved that the esophagus itself plays a small part in deglutition, and that the descent of the food bolus is due to the impetus given to it by the contraction of the pharyngeal muscles.

Since this time many surgeons have reported one or more cases in which this type of operation was performed with varying degrees of success. The list is so large that only references will be given: Frangenheim,[61] Heyrovsky,[62] Blauel,[63] Rehn,[64] Sÿring,[65] Axhausen,[66] Bornhaupt,[67] Hirschmann,[68] Fromme,[69] von Hacker,[70] Ranzi,[71] Peter-

59. Wullstein, L.: Zur plastischen Bildung eines neuen Oesophagus, Zentralbl. f. Chir. **35**:222, 1908.

60. Lexer, E.: Vollständiger Ersatz der Speiseröhre, München. med. Wchnschr. **58**:1548, 1911.

61. Frangenheim, Paul: Zur Frage der Oesophagus plastik, Arch. f. klin. Chir. **95**:684, 1911.

62. Heyrovsky, Hans: Wien. klin. Wchnschr. **27**:89, 1914.

63. Blauel, K.: Zur totalen Oesophagus plastik, Verhandl. d. deutsch. Gesellsch. f. Chir. **43**:119, 1914.

64. Rehn, Eduard: Oesophagus-Chirurgie, Jena, Gustav Fischer, 1914, p. 169.

65. Sÿring: Klinisches und Experimentelles zur Oesophagoplastik, Deutsche Ztschr. f. Chir. **128**:260, 1914.

66. Axhausen, G.: Zur totalen Oesophagoplastik, Berl. klin. Wchnschr. **1**:54, 1916; Die Technik der antethoracalen Totalplastik der Speiseröhre, Beitr. z. klin. Chir. **120**:163, 1920; Zur technik der Oesophagoplastik, Arch. f. klin. Chir. **139**: 645, 1926.

67. Bornhaupt, Leo: Zwei geheilte Fälle von totaler Oesophagoplastik, Arch. f. klin. Chir. **111**:315, 1919.

68. Hirschmann, Carl: Die Bedeutung und Technik des antethorakalen Speiseröhrenersatzes bei den impermeablen Strickturen, Therap. d. Gegenw. **60**:368, 1919.

69. Fromme, Albert: Ueber totale Oesophagoplastik, Beitr. z. klin. Chir. **115**: 222, 1919.

70. Von Hacker, Viktor: Zur antethorakalen Oesophagoplastik mittels Haut-Darmschlauchbildung, Zentralbl. f. Chir. **46**:1, 1919,

71. Ranzi, E.: Ueber totale Oesophagoplastik, Wien. klin. Wchnschr. **32**:247, 1919.

sen,[72] Kreuter,[73] Madlener,[74] Bohmansson,[75] Hinz,[76] Lotheissen,[49] Frangenheim,[77] Nigol,[78] Király,[79] Bakay,[80] Strahle,[81] Flechtenmacher,[82] Riesenkampff,[83] Jankovskis,[39] Sebestýen,[84] Denk,[85] Pokotilo [86] and Albrecht.[87]

Colon (Isoperistaltic).—In 1911, Kelling,[88] impressed by Lexer's [60] successful case which had just been reported, decided to attempt a similar operation, and chose as his patient a man, aged 45 with an ulcerating esophageal carcinoma. When the abdomen was opened he noticed the shortness of the mesentery of the small intestine as compared to that of the transverse colon, and therefore decided to try the suitability of this part of the large intestine for esophagoplasty. He resected a large piece of the transverse colon, reestablished the continuity by end-to-end anastomosis, closed the right end of the resected portion and anastomosed its left aboral end to the anterior surface of

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72. Petersen: Demonstration eines Falles von antethorakaler Oesophagusplastik bei kongenitaler Oesophagusstenose, Zentralbl. f. Chir. **48**:520, 1921.

73. Kreuter, E.: Zur Technik der antethorakalen Oesophagoplastik, Zentralbl. f. Chir. **47**:1266, 1920.

74. Madlener, Max: Ueber den Ersatz der Speiseröhre durch antethorakale Schlauchbildung, Deutsche Ztschr. f. Chir. **155**:410, 1920.

75. Bohmansson, Gösta: Antethoracal Oesophageal Plastic Operation, Acta chir. Scandinav. **53**:91, 1921.

76. Hinz, R.: Zur präthorakalen Oesophagusplastik, Deutsche med. Wchnschr. **47**:1089, 1921.

77. Frangenheim, Paul: Oesophagoplastik Methodik und Erfolge, München. med. Wchnschr. **69**:303, 1922.

78. Nigol, Karl: Dermoentero oesophagoplastica antethoracalis, abstr. Zentralorg. f. d. ges. Chir. **26**:309, 1924.

79. Király, J.: Drei Fälle extrathorakaler Oesophagoplastik, abstr. Zentralorg. f. d. ges. Chir. **32**:26, 1925.

80. Bakay, L.: Zwei Fälle von extrathorakale Oesophagoplastik, abstr. Zentralorg. f. d. ges. Chir. **32**:26, 1925.

81. Strahle, Lennart: Ein Fall von antethorakaler Oesophagusplastik, Acta chir. Scandinav. **58**:1, 1925.

82. Flechtenmacher, C., Jr.: Zur totalen antethorakalen Oesophagoplastik, Wien. med. Wchnschr. **75**:2590, 1925.

83. Riesenkampff, Otto: Ein Fall von totaler Oesophagoplastik, Deutsche Ztschr. f. Chir. **193**:116, 1925.

84. Sebestýen, Julius: Ueber Mechanismus und Wert der künstlichen Speiseröhre, Deutsche Ztschr. f. Chir. **193**:238, 1925.

85. Denk, W.: Ueber den Ersatz der Speiseröhre durch antethorakale Plastik, Wien. med. Wchnschr. **76**:582, 1926.

86. Pokotilo, V.: Ein Fall von antethorakaler Oesophagusplastik nach Roux, 3 Jahre lang verfolgt, abstr. Zentralorg. f. d. ges. Chir. **37**:333, 1927.

87. Albrecht, P.: Dermato-Jejunoplastik des Oesophagus, Wien. med. Wchnschr. **76**:1121, 1926.

88. Kelling, G. E.: Oesophagoplastik mit Hiffe der Querkolon, Zentralbl. f. Chir. **38**:1209, 1911.

the stomach near the fundus. The mesentery of the resected portion of the colon was preserved completely only at its left end and thus contained the left colic artery. A Kader type of gastrostomy was performed. The colon was drawn up onto the anterior thoracic wall, the skin of which was incised and undermined to receive it. The colon was laid in the subcutaneous channel and the skin sutured over it. The blind end of the colon was sutured to the upper part of the skin wound. The patient was nourished through the gastrostomy opening for a few days, and then the blind end of the colon was opened and the mucous membrane sutured to the skin. About a month after the first operation, the esophagus was brought out of the neck, and an attempt was made to bridge the gap between the esophageal fistula and the upper end of the colon. The patient collapsed and died when everything seemed to be going well.

Colon (Antiperistaltic).—In 1911 also, Vulliet [89] devised an operation similar to that of Kelling, but performed it only on the cadaver. The point of difference between the two methods is that Vulliet preserved the mesenteric pedicle at the right (oral) end of the resected intestine, and he anastomosed this end to the stomach, drawing the left (aboral) end up onto the chest. Thus, his arrangement of the resected portion of the colon was antiperistaltic. This did not worry Vulliet because of the observations of Lexer and Frangenheim which seemed to show that the peristalsis in such an excluded loop of intestine was hardly worth consideration.

The reports in the literature on esophagoplastic operations in which an excluded portion of the transverse colon was used have been few, and in those in which full reports are given the Kelling type of operation has been most commonly performed.

Von Hacker,[90] Fonio,[30] Lundblad,[91] Ritter [92] and Lotheissen [49] have all reported cases.

In 1923, Roith [93] devised a new one-stage method of esophagoplasty, using a part of the transverse colon and the cecum and ascending colon. He performed his operation on a man on whom gastrostomy had been performed for stricture of the esophagus. At the end of seventeen

89. Vulliet, H.: De l'oesophagoplastie et des diverses modifications, Semaine méd. **31**:529, 1911.

90. Von Hacker: Ueber Oesophagoplastik im allgemeinen und über den Ersatz der Speiseröhre durch antethorakale Haut-Dickdarmschlauchbildung im besondern, Arch. f. klin. Chir. **105**:973, 1914.

91. Lundblad, Olaf: Ueber antethoracale Oesophagoplastik, Acta chir. Scandinav. **53**:535, 1921.

92. Ritter: Diskussion, Zentralbl. f. Chir. **45**:521, 1921.

93. Roith, Otto: Die einzeitige antethorakale Oesophagoplastik aus dem Dickdarm, Deutsche Ztschr. f. Chir. **183**:419, 1923-1924.

days the patient was well enough to go home; the gastrostomy opening had closed. The patient fared well for three years, and then died of an intercurrent disease. Roith's procedure was as follows:

A large abdominal incision was made from the xiphoid process downward, at first vertically, then diagonally through the right rectus, as a good exposure is necessary. The cecum was loosened, the parietal peritoneum cut lateral to the ascending colon and this portion of intestine freed. The ileum near the ileocecal valve was cut through and both ends closed blindly. Transverse section was made of the middle of the transverse colon with blind closure of both ends, ileocolostomy by lateral anastomosis between the closed ends of the proximal ileum and the distal colon, and anastomosis between the aboral end of the excluded colon and the upper part of the anterior wall of the stomach. The cecal end of the colon was drawn up into the anterior thoracic wall subcutaneously to the neighborhood of the left clavicle where, after exposure of the cervical portion of the esophagus, anastomosis was made laterally by interrupted sutures to the cecum. This completed the one-stage esophagoplasty.

Comment.—Up to the end of 1921, Lotheissen [49] reviewed eighty-nine cases reported in the literature in which esophagoplasty for the relief of benign stricture had been performed by various methods. Forty-five of these operations were complete and 44 were incomplete. By the end of 1923, this number had been increased to 101 (von Hacker [70] and Lotheissen), with 50 complete and 51 incomplete. In 1926, Denk [85] added 19 complete cases from the literature to this list. He omitted, however, the cases of Sebestyén [84] (6 complete and 4 incomplete), Flechtenmacher [82] (1 incomplete) and Jankovskis [89] (4 complete and 1 incomplete), and since he wrote, the reports of Perthes,[94] Braizew [35] and Albrecht [87] have appeared, each of whom completed 1 case, of Grigorjev [50] and Pokotilo [86] whose cases were incomplete, and of Rovsing [95] (2 complete and 1 incomplete). These additions (a total of 24 cases) are the result of a search in the literature up to the end of 1927, and make the total number of recorded esophagoplastic operations for benign stricture 144, of which 84 have been completed, with 60 incomplete. Death, sometimes from intercurrent diseases but usually resulting from the operative procedures, has been the most common reason for incompletion: in the list compiled by von Hacker and Lotheissen it accounted for 25 of the incomplete cases, while in my additional 9 incomplete cases reviewed from the literature there were 5 deaths. The total mortality amounts to 20.8 per cent.

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94. Perthes: Plastischer Ersatz der nach Laugenverätzung verschlossenen Speiseröhre (Krankenvorstellung), München. med. Wchnschr. **73**:1465, 1926.

95. Rovsing (footnotes 33 and 34).

The case reports show an overwhelming preponderance of jejunoplasty by means of skin over the other types of jejunoplasty. This is particularly noticeable in the most recent cases: for example, in my collection of 24 cases. Only those of Rovsing,[95] Braizew [35] and Grigorjev [50] were done by other methods, leaving 18 which were performed by the Wullstein-Roux-Herzen type of operation.

It can be seen from the foregoing account of the esophagoplastic procedures that in a case of impermeable stricture the surgeon has the choice of several types of operation. They may be divided into two groups: those in which an abdominal viscus is used (beyond simple gastrostomy) and those in which the entire antethoracic esophagus is made from the skin of the wall of the chest.

The first group suffers from two disadvantages which are common to all types of operation belonging to it, whether the stomach, jejunum or colon is used. They are the risks of gangrene of the antethoracically transposed viscus due to insufficiency of, or interference with, its blood supply, and peritonitis. Although the latter is usually successfully guarded against by the adoption of present-day methods of surgical technic, the former must always remain a much more serious risk since it is dependent on several factors.

The disadvantages of jejuno-esophagoplasty as performed by Roux are at once apparent. The loop of jejunum was so long that its blood supply could not be otherwise than poor. Moreover, by bringing up the loop in front of the transverse colon, the mesenteric pedicle was twisted, and there was risk of compression of the colon by it. Herzen corrected these faults by his modification of bringing up the jejunal loop through an incision in the mesocolon, thereby passing it behind the transverse colon. Hirschmann [96] suggested another improvement by making the skin tube so that its lower end is at the level of the xiphoid process, thus further shortening the length of the jejunal loop necessary for this operation, ensuring a much better blood supply and preventing the blind saclike dilatations near its juncture with the stomach which have sometimes given cause for resection.

Kirschner's [52] method has the advantage that, with the exception of the anastomosis of the cervical portion of the esophagus with the stomach, the whole operation is done in one stage. It presents two difficulties, however: the anastomosis of the cardiac end of the esophagus (or the remaining cardiac part of the stomach) with the small intestine and the transposition under the skin of such a large viscus. The work of Miller and Andrus,[54] and later that of Wajgiel,[55] and the occurrence of a perforating gastric ulcer in one of Kirschner's cases would seem to indicate that the blood supply of such a mobilized

96. Hirschmann, Carl: Komplikationen bei der totalen Oesophagoplastik, Ihre Beseitigung und Verhutung; zugleich ein Beitrag zur Verwendung der "Epithaleinlage," Arch. f. klin. Chir. **122**:553, 1922.

stomach may, in a fair percentage of cases, prove to be so inadequate as to prevent the adoption of this type of esophagoplasty in preference to others.

Next to jejuno-esophagoplasty the method of Beck and Jianu has won most favor. Its disadvantages lie in the long suture line and in the production of acid and pepsin by means of the mucous membrane, the corrosive effect of which may seriously compromise healing. Most cases in which this method was used seem to have been successful in spite of the doubt cast on it by the experiments of Enderlen and Hotz, who found gangrene of the tube formed from the stomach in every case. Meyer and Lotheissen both regard this method as the best type of esophagoplasty.

In the Kelling and Vulliet type of operation, it is thought that the risk of peritonitis is considerable because of the virulence of the organisms usually found in this part of the bowel. There is also to be considered the difficulty of bringing up the colon subcutaneously, owing to its bulk. In these cases there is a tendency for food to collect and remain for some time on the lower part of the transposed loop before it passes into the stomach; this may affect the comfort of the patient.

In this group all the acids of the viscera are capable of peristaltic movement and may be transposed in either an isoperistaltic or an antiperistaltic way. If in the former, then peristalsis, although usually it does not greatly help the functional results, at least is not detrimental to it. When the viscus is placed in an antiperistaltic manner, one would expect that peristalsis would adversely affect the function of the new esophagus. Under these circumstances, however, it behaves in such a paradoxic way that it seems impossible to foretell the result. Sÿring arranged his jejunal loop antiperistaltically, and peristalsis, by causing a copious regurgitation of gastric juice, led to complete failure of the operation. On the other hand, Jankovskis performed a similar type of operation, and had no trouble whatsoever from this source.

In the second group fall the method of skin esophagoplasty of Bircher [27] and its modifications. These have a great advantage over the methods in the first group in that the only intra-abdominal operation necessary is simple gastrostomy, which in many cases has already been done as a palliative measure some time before it was decided to undertake the formation of an antethoracic esophagus, thus rendering any subsequent intra-abdominal procedure increasingly difficult because of adhesions. It has been realized that peristaltic action in an artificial esophagus is unnecessary; the cases of Torek [97] and of Eggers [98] are

97. Torek, F.: The First Successful Case of Resection of the Thoracic Portion of the Oesophagus for Carcinoma, Surg. Gynec. Obst. **16**:614, 1913.

98. Eggers, Carl: Resection of the Thoracic Portion of the Esophagus for Carcinoma: Report of a Successful Case, Arch. Surg. **10**:361 (Jan.) 1925.

proof of this. The formation of the tube of skin in males is likely to be difficult because of the tightness of the anterior thoracic skin, but tension can usually be relieved by means of suitably placed incisions. Judging from the literature, the least difficult and most successful part of any total antethoracic esophagoplasty is the formation of the skin tube.

Common to both groups are the difficulties that accompany the esophagostomy. There is often a marked tendency to stenosis. This should be overcome by the passage of bougies or by small plastic operations before anastomosis with the upper end of the skin tube is attempted. Some authors advise the direct union of the esophagus with the upper edge of the skin tube; others, that it should be united first with the skin of the neck and afterward the two orifices enclosed by a small tube of skin. The flow of saliva from the esophagostomy opening generally retards healing at this point. Some of the earlier workers were content to make only partial division of the esophagus and to unite the cut edges to the skin. This practice has been superseded by transection, on the grounds that by the former method food gained access to the culdesac above the stricture, resulting in stagnation and infection.

At the lower end of the skin tube the corrosive effect of the regurgitated gastric juice may retard healing at its juncture with a transposed abdominal viscus or the gastrostomy, causing fistula and necessitating many minor plastic operations.

Although many successful attempts have been made to form an artificial esophagus by antethoracic esophagoplasty, the surgeon who undertakes the operation should realize that he accepts a grave responsibility. It takes months to complete the procedure, the mortality is not low and success is far from being assured even if death does not occur. The avoidance of the necessity of the operation depends largely on a proper understanding of the term impermeable.

It has been known for many years that a swallowed silk thread will often worm its way through a stricture through which the smallest bougie cannot hope to penetrate. This fact formed the basis of von Hacker's [99] successful "sondierung ohne Ende" method of treating benign stricture. The lower end of the silk thread is drawn out of a gastrostomy opening, while a rubber tube is attached to the upper end, which is drawn downward through the stricture by pulling on the lower end of the thread. The upper end of the rubber tube is in turn attached to one of greater diameter, and this is next drawn down through

99. Von Hacker: Zur Behandlung tiefsitzender Narbenstricturen der Speiseröhre durch Sondierung ohne Ende nach temporärer Gastrostomie Oesophagostomie mit Bemerkungen über die Verwendung ausgezogener Drains zur Drainage ohne Ende, Wien. klin. Wchnschr. **7**:455 and 480, 1894.

the stricture. By a continuation of this process, rubber tubes of gradually increasing diameters can be used to dilate the stricture to the required size. This method was modified by Dunham [100] who made use of metal sounds instead of rubber tubes. Mixter [101] went a step further and introduced a modification of Dunham's technic which abolished the necessity of gastrostomy. He conceived the idea of using a silk thread which had passed through the stomach into the intestine, far enough to admit of its being drawn taut, as a guide for passing dilating sounds through the stricture. H. S. Plummer [102] recognized the value of this method and introduced it into the Mayo Clinic where it is now carried on successfully by Vinson.[103] Many of Vinson's patients who have had gastrostomy performed for "impermeable" stricture, and others who, according to the roentgenologist, had complete occlusion, have swallowed a thread and it passed through the stricture, in spite of the fact that even the smallest sound failed to pass. He has not failed to dilate successfully in any such case. Reports in the literature show that many of these plastic procedures have been undertaken simply because the smallest bougies could not be passed through the stricture, and in view of the foregoing facts it would seem that many patients have been submitted unjustifiably to operations of long duration and considerable risk. No doubt there are rare cases in which anatomic impermeability occurs, and the lumen is completely occluded or at any rate obliterated to such an extent that all efforts to get a silk thread to pass through the stricture are of no avail. On the other hand, it should be recognized that in almost all severe cases the impermeability is only clinical and not anatomic, and can be satisfactorily treated by the well tried and successful method which has been described.

If a stricture finally becomes anatomically impermeable, it means that the stricture must have passed through the stage of clinical impermeability, at which time it was either neglected or wrong, or insufficient treatment was instituted. During its passage from clinical to anatomic impermeability, gastrostomy must have been performed; otherwise, the patient would have died from starvation. Hence, all patients who have an anatomically impermeable, benign, cicatricial stricture have been submitted also to gastrostomy. The question of further surgical intervention by the formation of an artificial esophagus now arises and

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100. Dunham, Theodore: New Instruments for the Treatment of Oesophageal Stricture, Ann. Surg. **37**:350, 1903.

101. Mixter, S. J.: Symposium on the Surgery of the Oesophagus, from the Standpoint of the General Surgeon, Tr. Am. Laryngol. A. **31**:342, 1909.

102. Plummer, H. S.: The Value of a Silk Thread as a Guide in Esophageal Technic, Surg. Gynec. Obst. **10**:519, 1910.

103. Vinson, P. P.: Personal communication to the author.

is dependent on the efficiency of the gastrostomy. Should the patient be satisfied with this, nothing further need be done. On the other hand, should the gastrostomy prove inefficient and bring unbearable discomfort in its train, then antethoracic esophagoplasty is justifiable, provided that the risks and uncertainty of success are pointed out to the patient and he is willing to allow the surgeon to operate on the chance of success, which, if achieved, will allow him to take his place once again as a normal person.

Here a plea is made for the prevention of the progression of benign cicatricial stricture to either clinical or anatomic impermeability. So often the histories of patients suffering with this condition are stories of neglect, on the part either of the patient or of one or more physicians. Rutherford Morison's aphorism "Once a stricture, always a stricture" is as true of the esophagus as it is of the urethra, and if such patients were told this and were impressed with the likelihood that the stricture might become impermeable if not treated properly, there is no doubt that their negligence, often the outcome of ignorance, would be largely prevented. Thus, regular systematic dilatation could be undertaken and started shortly after the onset of the affliction. In this way cases of impermeable stricture would be reduced considerably or might be abolished altogether, although some authors hold the opinion that in rare cases the progression of a stricture to impermeability apparently cannot be prevented.

RESECTION WITH OR WITHOUT ACCOMPANYING PLASTIC OPERATIONS

The goal for which surgery is ever striving in esophageal work is successful resection for carcinoma. The difficulties in obtaining successful results have been discussed. They are as yet far from being surmounted with any degree of regularity. Judging from the literature, it would seem that every method which ingenuity can invent has been practiced for the purpose of reestablishing the continuity of the esophagus after resection either in the dog (the animal most frequently used for experimental esophageal surgery) or in man.

Cervical Portion.—The earliest reports concerning resection of the cervical portion of the esophagus are those of Billroth [104] and Czerny.[105]

Billroth,[104] in 1871, was the first to turn his attention to resection of the esophagus, with extirpation of carcinoma as his ultimate object. He performed the operations on dogs. After exposing the esophagus, he freed it from the surrounding connective tissue, resected about 1.5 cm.

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104. Billroth, T.: Ueber die Resection des Oesophagus, Arch. f. klin. Chir. **13**:65, 1871.

105. Czerny, quoted by von Hacker: Arch. f. klin. Chir. **87**:257, 1908.

and sutured the cut ends together. The first dog died in five days from a phlegmon of the neck. The second dog fared better; a fistula formed which discharged for several months but finally healed, and the dog lived in health until it was killed.

In 1877, Czerny,[105] one of Billroth's pupils, was the first to extirpate successfully the cervical part of the esophagus for carcinoma in a human being. He made the usual incision along the anterior border of the left sternomastoid and removed the portion of the esophagus from just below the pharynx to below the thyroid gland, thus being well clear of the tumor above and below; in all, about 6 cm. of the esophagus was removed. The distal end of the esophagus was stitched into the lower part of the skin wound, and the patient was fed by tube through the esophagostomy opening. She died fifteen months after the operation from recurrence.

In 1884, Mikulicz [106] went a step further; he followed resection of a cervical esophageal carcinoma with plastic repair of the fistula resulting from the operation. Four months after the first operation, he cut out the fistula with its surrounding skin, and on each side cut a small flap of skin with its base medially. He turned these flaps inward so that the epidermis was inside, and sutured their edges together. The skin lateral to the flaps was drawn together over them by means of silver wire sutures. The wound healed by first intention, and after ten days the patient was able to swallow solid food. Death from recurrence occurred sixteen months after resection.

Mikulicz' plastic operation was an afterthought, and von Hacker,[107] in 1886 and 1887, appears to have been the first to attempt partial and complete removal of the circumference of the cervical portion of the esophagus with the express intention of following the operation immediately with the replacement of the esophageal defect by the skin of the neck. He first experimented on dogs and performed two types of operation, either leaving posteriorly a longitudinal strip of esophageal wall from 1 to 2 cm. in width or removing the whole circumference. In the first type he reconstructed the posterior esophageal wall by lateral flaps of skin. In the second, instead of employing a vertical incision in the skin, he made two horizontal incisions distant from one another slightly more than the length of the portion of the esophagus to be resected, thus forming a bridge of skin which when undermined was freely movable. After resection, the bridge of skin was dropped back into the wound, and its upper and lower edges sutured to the posterior edges of the corresponding esophageal orifices, thus reconstructing the

106. Mikulicz, J.: Ein Fall von Resection des carcinomatösen Oesophagus mit plastischem Ersatz des excidirten Stückes, Prag. med. Wchnschr. **11**:93, 1886.

107. Von Hacker, Victor: Zur Pharyngo- und Oesophagoplastik, Zentralbl. f. Chir. **18**:121, 1891.

posterior wall of the esophagus. In both types he undertook to reconstruct the anterior wall of the esophagus by the formation of two rectangular flaps of skin, the outer edges of which he turned medially and sutured together in the median line. The skin lateral to the flaps was undermined enough to permit of its being drawn together over the inverted flaps of skin and sutured over them (Bircher [27] employed the same principle on a larger scale for his antethoracic skin tube).

The opportunity to carry out the operation on a human subject presently came to von Hacker.[107] He formed two rectangular flaps of skin before performing the resection, but as he left none of the esophageal wall behind, he brought the flaps together, sutured them in the median line and stitched their upper and lower angles to the circumference of the posterior esophageal wall. Before the second step of completing the skin tube by the formation of the anterior wall from the flaps of skin, the patient died.

In 1898, Garrè [108] published a report of three cases of carcinoma in the cervical portion of the esophagus, in which he performed resection. One patient lived for about a year after the operation. In another case the larynx was extirpated also and its mucous membrane used successfully for esophagoplasty, being sutured to the pharynx above and the esophagus below, thus forming a new posterior esophageal wall.

In 1908, von Hacker [109] reported the work done up to that time on resection of the cervical portion of the esophagus. Altogether, he reviewed twenty-five cases from the literature. In almost all of them plastic repair had been attempted, but was completed in only a few cases. The most interesting fact to be gleaned from his report is that, except for his own second case, Czerny's patient lived the longest after operation (fifteen months). That this patient thirty-one years previously had been the first to undergo resection of the cervical portion of the esophagus indicates clearly the lack of progress in this type of surgery up to this time. In 1908, von Hacker described his second case, in which, after preliminary gastrostomy, resection of nearly all the cervical portion of the esophagus was undertaken, together with the total extirpation of the larynx and the trachea down to a short distance above the jugular notch. The trachea was sutured to the skin, and the first stage of the plastic operation was done by suturing a right-sided rectangular flap of skin into the esophageal defect. Later he performed the second stage, completing the formation of the tube of skin by turning inward the two rectangular flaps of skin, joining them together in the median line

108. Garrè, C.: Ueber Oesophagus-Resection und Oesophagoplastik, Arch. f. klin. Chir. **57**:719, 1898.

109. Von Hacker, Victor: Ueber Resection und Plastik am Halsabschnitt der Speiseröhre, insbesondere beim Carcinom, Arch. f. klin. Chir. **87**:257, 1908.

and covering them with two lateral flaps, one longer than the other, so that the suture line was to one side and not in the median line. The third stage consisted in completing the juncture between the pharynx and skin tube. After fourteen months the patient had gained 19 Kg. (40 pounds), and on examination at the end of sixteen months after the operation was in good health.

In 1911, Lane [110] introduced the single skin-flap method for plastic repair after resection of the cervical portion of the esophagus He cut a horizontal flap 5 cm. deep and 12.5 cm. long with its base to the left of the neck. The flap was then reflected toward its base. The upper part of the esophagus was exposed and the carcinoma removed with a margin of uninvolved esophageal wall. The removed segment of esophagus was then replaced by folding the flap in the form of a tube in the longitudinal axis of the esophagus. The upper margin was sutured to the pharynx and the lower to the divided esophagus. After a sufficient interval for firm union of the skin esophagus to the portions of the normal esophagus at the lines of section, the attachment of the skin flap by its base to the skin of the neck was divided, and any lateral aperture which remained in the skin esophagus was closed. The danger of necrosis of the skin flap is in direct proportion to its length. The patient progressed for some time, but death occurred seven months after the operation from perforation of the carotid artery due to recurrence of the growth. Two years later, Ach [111] attempted an operation similar to that of Lane. His patient died soon afterward.

In 1913, Gluck,[112] commenting on the 48 per cent operative mortality among the twenty-five cases reviewed in the literature by von Hacker [109] in 1908, reported that he had operated in forty-seven such cases with only five deaths.

The experiments which have led to the attempted replacement of a resected portion of the esophagus by fascia had their origin in those of König,[113] in 1911, who successfully reinforced esophageal suture lines by a flap of cervical fascia and platysma. Kostenko and Rubaschew [114] went a step further and succeeded in replacing small oval resected por-

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110. Lane, W. A.: Excision of a Cancerous Segment of the Oesophagus, Restoration of the Oesophagus by Means of Skin Flap, Brit. M. J. **1**:16, 1911.

111. Ach, A.: Beiträge zur Oesophagus-Chirurgie, Munich, J. F. Lehmanns, 1913, 132.

112. Gluck: Ueber Oesophago-, Pharyngo- und Laryngo-plastik, Berl. klin. Wchnschr. **35**:938, 1898; Erfahrungen auf dem Gebiete der Chirurgie der oberen Luft- und Speisewege, ibid. **50**:953, 1913.

113. König, Fritz: Neue Wege der plastichen Chirurgie (Verlöthung und Ueberbrüchung), Arch. f. klin. Chir. **95**:326, 1911.

114. Kostenko, M. F., and Rubaschew, S. M.: Ueber die freie Fascientransplantation, abstr., Zentralbl. f. Chir. **39**:1448, 1912.

tions of the cervical part of the esophagus. Razzaboni,[115] using the peritoneum and sheath of the rectus abdominis, and Neuhof,[116] with autogenous fascia lata, did similar work.

Allen,[117] in 1923, was the first to attempt the experimental replacement of the whole circumference of the resected esophagus by autogenous fascia lata. His efforts to do this in one stage were all failures because of fatal cellulitis and mediastinitis. He therefore devised a two-stage method, first placing two tubes of fascia around the esophagus, the outer tube being the longer. After several days he split the outer tube and removed the inner with the esophagus contained in it. By this method most of the animals survived, although stenosis developed in all cases. Later, Allen[118] developed a technic for removing a portion of esophagus inside a fascial sleeve without splitting the sleeve. He placed two stout ligatures around the esophagus a short distance apart, enveloped this portion by a sleeve of fascia lata, and brought out the ends of the ligatures through the fascia. After a few days the ligatures were tied tightly, and the esophagus sloughed between them, the necrotic tissue being swallowed. In two of seven cases he failed to secure sloughing, because the ligatures were not tied tightly enough. In the remaining five cases, stenosis developed.

Neuhof and Ziegler[119] advocated a granulation tube method for reconstruction of the esophagus after resection. The first stage consisted of isolating the esophagus and packing it off from the surrounding structures. A week later, the packs were removed and granulation tissue had formed under them. The segment of esophagus was then excised, and a soft rubber tube securely sutured in its place. Granulations formed around the tube, which became loose and was removed. A fistula formed but finally closed completely. All the animals survived this two-stage operation, although all attempts to perform it in one stage ended in fatal cellulitis.

Schönbauer and Orator[120] performed experiments similar to those of Allen,[121] using an inner and outer tube of peritoneum. One animal

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115. Razzaboni, Giovanni: Ricerche sperimentali sull'autoplastica ésofagea per mezzo del trapianto di lembi liberi musculo-aponeurotico-peritoneali, Policlinico **24:** (Sect. Chir.) 417, 1917.

116. Neuhof, Harold: Fascia Transplantation into Visceral Defects: An Experimental and Clinical Study, Surg. Gynec. Obst. **24:**383, 1917.

117. Allen, D. S.: Experimental Reconstruction of the Esophagus with Autogenous Fascia Lata Transplants, Ann. Surg. **76:**157, 1922.

118. Allen, D. S.: Further Experimental Reconstruction of the Esophagus with Autogenous Fascia Lata Transplants, Arch. Surg. **10:**374 (Jan.) 1925.

119. Neuhof, Harold, and Ziegler, J. M.: Experimental Reconstruction of the Oesophagus by Granulation Tubes, Surg. Gynec. Obst. **34:**767, 1922.

120. Schönbauer, Leopold, and Orator, Viktor: Peritoneal Transplantation zur Oesophagusnaht, Arch. f. klin. Chir. **129:**806, 1924.

121. Allen (footnotes 117 and 118).

lived for a year. The latest report in the literature on experimental surgery of the cervical portion of the esophagus is that of Carrington.[122] After clamping the esophagus with two Kocher clamps, he placed a row of interrupted silk Lembert sutures all around and then cut through the esophagus between the clamps. The sutures were drawn tightly and the clamps released and withdrawn. The sutures were again drawn tightly as the clamps were removed, and this time were tied. Another similar layer of interrupted Lembert sutures was placed outside the first row. Each suture included muscle and adventitia. The wound in the neck was closed tightly. The experiment on only one dog was successful; fatal mediastinitis developed in all the other dogs, or, more commonly, sloughing of the esophagus that failed to hold. Carrington then changed his technic. After mobilization, the esophagus was surrounded by two narrow tapes about 5 cm. apart tied tightly enough to prevent leakage without injury of the muscular coat. An antiseptic solution, such as mercurochrome-220 soluble or a weak solution of iodine or chlorine, was introduced through a needle into the esophageal lumen between the two tapes. After time had elapsed for sterilization, the esophagus was divided and cut ends sutured together with three rows of sutures, the first continuous through all layers, the second an interrupted Lembert suture and the third consisting of six Lembert sutures which took in a long bite of tissue and were drawn only sufficiently tight to relieve the tension on the first two rows. Of eighteen such operations, he succeeded in nine; in most of the nine failures the esophagus was totally or partially divided, with resultant extensive cervical infection often associated with purulent mediastinitis. In one case only was there marked stricture, and even then the dog was kept in excellent condition. Carrington always sutured the cut ends of the esophagus with the viscus fully expanded, and it was on this part of his technic that he explained the absence of stricture in his results.

Thoracic and Cardiac Portions (End-to-End Anastomosis).—Although the cardiac portion of the esophagus is intraperitoneal, the operations on it and on the intrathoracic portion are so intimately connected that the operative procedures on these two parts of the esophagus will be considered simultaneously.

Resection of the thoracic and cardiac portions of the esophagus followed by end-to-end anastomosis has not yet passed beyond the experimental stage, as the clinical indications for its performance are not likely to be encountered frequently.

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122. Carrington, G. L.: Experimental Surgery of the Esophagus: Some Factors and End Results, Ann. Surg. **86**:505, 1927.

In 1901, Dobromysslow [123] reported the first successful intrathoracic suture of a resected esophagus. He made a large skin flap with its base posteriorly, extending from the sixth to the tenth rib vertically; it was about from 10 to 15 cm. in length. Resection of the ribs probably followed, although this was not mentioned. After incising the parietal pleura and laying bare the lower part of the esophagus, he divided the vagi and resected from 3 to 4 cm. He united the ends by two rows of silk sutures. Before the thoracic flap was sutured in place, the air was sucked out of the pleural cavity by negative pressure. Three weeks later, complete union of the suture line was found to have taken place, with slight proximal dilatation of the esophagus.

In spite of this apparent mastery of intrathoracic esophageal surgery, subsequent work in the same direction has not fulfilled the promise of success which Dobromysslow's performance seemed to give, even though shortly afterward the differential pressure chamber invented by Sauerbruch and the positive pressure apparatus of Brauer came into use and by their prevention of collapse of the lung during operation and pneumothorax afterward gave a great impetus to intrathoracic surgery.

In 1905, Sauerbruch [124] published two articles dealing with his experimental intrathoracic work on dogs. He introduced the intercostal incision in place of the more tedious and mutilating flap and resection method. Opening a pleural cavity through an intercostal incision is so simple and gives such excellent exposure of the thoracic part of the esophagus that it has been universally adopted in experimental work. Sauerbruch first of all tried end-to-end suture of the esophagus after resection and met with little success as his sutures continued to tear out.

In 1913, Omi and Karasawa [125] obtained some surprisingly good results in experimental operations on the thoracic portion of the esophagus. They used silk sutures in three layers, the first through the mucosa, the second through the muscle and adventitia and the third a continuous external Lembert suture. Of nine divisions of the esophagus with end-to-end anastomosis, seven were successful. In consequence of their results, they felt that a carefully made suture of the esophagus is sufficiently reliable to warrant its adoption in operations on human beings.

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123. Dobromysslow, W. D.: Ein Fall von transpleuraler Oesophagotomie im Brustabschnitte, abstr., Zentralbl. f. Chir. **28**:18, 1901.

124. Sauerbruch, F.: Die Chirurgie des Brustteils der Speiseröhre: Eine experimentelle Studie, Beitr. z. klin. Chir. **46**:405, 1905; Die Anastomose zwischen Magen und Speiseröhre und die Resektion des Brustabschnittes der Speiseröhre, Zentralbl. f. Chir. **32**:81, 1905.

125. Omi, K., and Karasawa, Z.: Beitrag zur Chirurgie der Speiseröhre, Deutsche Ztschr. f. Chir. **124**:574, 1913.

Thoracic and Cardiac Portions (Esophagogastrostomy).—Esophagogastrostomy as a method of restoring the continuity of the alimentary tract after resection of the thoracic portion of the esophagus has proved more popular than any other operation for this purpose.

Biondie,[21] in 1895, was the first to carry out this procedure, performing it on dogs. To him also goes the credit of being the first to expose the esophagus by the transthoracic route. He employed a paravertebral incision followed by the resection of two or three ribs and incision of the parietal pleura. The stomach was pulled up through the diaphragm, the lower end of the esophagus cut through and the oral end sutured into the fundus of the stomach, which was then replaced in the abdomen. Biondie stated that the technic was difficult, particularly on account of the movement of the diaphragm, and pointed out that in the human subject the amount of esophagus to be resected for carcinoma might be so great that replacement of the stomach in the peritoneal cavity after the esophagogastrostomy might not be possible.

In 1904, Mikulicz [126] gave an account of his researches in intrathoracic surgery carried out in the Sauerbruch differential pressure chamber. He pointed out that it is difficult enough to reunite a transected esophagus because of tension, but much more difficult to reunite one in which a portion has been resected. Therefore he let alone the direct juncture of the two ends after resection and devised two other methods of dealing with the problem, the choice of method depending on whether the portion to be resected was at the lower end or higher up in the thorax. In the first case, after opening the pleural cavity, he pulled up the stomach and anastomosed it to the oral end of the resected segment of the esophagus. He found that in dogs and cadavers a good part of the cardiac end of the stomach could be drawn up into the pleural cavity. The wall of the stomach was stitched to the margin of the diaphragmatic opening, and the esophagogastric juncture remained within the pleural cavity. One dog in which this operation was performed had, at the time of writing, lived six weeks without any disturbance of digestion or nutrition. Another animal, in which 2.5 cm. of the lower end of the esophagus had been removed and esophagogastrostomy performed in this way, lived four weeks, and at necropsy the suture line was found to be intact and moderately stenosed. Disease of the lungs or pleura was not present. Mikulicz suggested that the displaced stomach might be replaced in the abdomen and the diaphragm sutured to the esophageal wall above the esophagogastric juncture which would thus become intraperitoneal. He performed this operation several times.

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128. Voelcker: Ueber Exstirpation der Cardia wegen Carcinoms, Verhandl. d. Verhandl. d. deutsch. Gesellsch. f. Chir. **27**:252, 1898.

In 1905, Sauerbruch,[124] because he considered tension the main cause of failure in his work on end-to-end anastomosis of the esophagus after resection, brought up the stomach into the pleural cavity and anastomosed the oral end of the resected segment of the esophagus to it both by end-to-end anastomosis and by implanting the esophagus into the stomach like the tube in a Witzel gastrostomy. In most of his experiments the sutures tore out. These failures led him to adopt the button for intestinal anastomosis. This proved so successful that he abandoned the use of sutures altogether. He stated that he had operated on eleven dogs without a death, although more than 7 cm. of the esophagus was resected. He also introduced a two-stage operation for the removal of the cardiac portion of the esophagus. The first stage consisted of thoracotomy with transection of the lower part of the esophagus and inversion of the lower end into the stomach followed by esophagogastrostomy. The second stage was undertaken after fourteen days, at which time laparotomy was performed, the stomach opened and the intragastric esophageal projection cut off; the stomach and laparotomy wound were closed. He performed this operation on cadavers and believed it to be feasible on the living subject. He mentioned clinical experience in three cases in which thoracotomy had been performed with a view to resection of esophageal carcinoma. All three tumors proved to be inoperable, and all the patients died.

In 1907, Wendel [127] operated on a patient who had carcinoma of the cardia and lower end of the esophagus; he used the transpleural route, bringing up the stomach through the diaphragm. After resection of the growth, he closed both the esophagus and the stomach and performed lateral esophagogastrostomy by means of a button. The patient died the next day of hemorrhage. This is the first case reported in which this operation was performed on a living subject.

In 1908, Voelcker [128] reported the first successful case of extirpation of a carcinoma of the cardia following two failures. After laparotomy through an incision parallel to the left costal margin, he cut the cardia below the tumor, freed the esophagus at its hiatus and pulled down about 4 cm. Then the esophagus was cut through above the tumor, and its oral end anastomosed to the stomach near its greater curvature. Gastrostomy was performed near the pyloric end. After four weeks of feeding through the fistula, nutrition by mouth was begun. In another month the fistula closed, and the patient ate normally. Data concerning this case have not appeared in the literature subsequently.

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127. Wendel, W.: Beitrag zur endothorakalen Oesophaguschirurgie, Arch f. klin. Chir. **83**:635, 1907.

128. Voelcker: Ueber Exstirpation der Cardia wegen Carcinoms, Verhandl. d. deutsch. Gesellsch. f. Chir. **37**:126, 1908.

In 1909, Meyer [129] emphasized the importance of avoiding contamination of the mediastinum and pleura with the highly infectious esophageal mucous secretion, and devised a method of esophagogastrostomy whereby he sought to achieve this end. The essential points were: (1) drawing up the stomach into the pleural cavity and suturing the diaphragmatic peritoneum to the wall of the stomach; (2) division of the esophagus below the supposed tumor between a clamp below and a ligature above followed by inversion of the distal stump; (3) division of the esophagus above the supposed tumor between the clamp below and a ligature of absorbable catgut above; (4) incision of the stomach through serosa and muscularis and suture of the upper edge to the posterior wall of the esophagus with two layers; (5) opening of mucous membrane of the stomach and introduction of the ligated oral end of the esophagus, and (6) completion of the esophagogastric juncture by two layers of sutures between the lower edge of the incision in the stomach and the anterior wall of the esophagus. In six dogs operated on by this method, two functioning anastomoses were obtained. Meyer suggested: 1. Stricture may be avoided by dividing the esophagus with scissors instead of cautery, as burns show a greater tendency to contract than cuts, and that the esophagus should be divided obliquely instead of at right angles to its longitudinal axis if length permits. 2. Contraction of the gastric wound around the esophagus can be averted by elliptical excision of the serosa followed by a linear incision of the mucosa.

In 1909, Janeway and Green [130] operated on a large series of dogs, performing intrathoracic esophagogastrostomy alone; after resection of the lower part of the esophagus they used a specially designed button and reinforced the anastomosis thus made by suture. In sixty-nine operations, they successfully accomplished resection of the cardia and lower thoracic portion of the esophagus in four cases and lateral anastomosis without resection in six. They stated that their work demonstrated that speed, absolute asepsis and scrupulous care in the minimizing of trauma are essentials of success in esophageal operations. For these reasons, they adopted the button instead of sutures for anastomosis.

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129. Meyer, Willy: Oesophagogastrostomy After Intrathoracic Resection of the Oesophagus, Ann. Surg. **50**:175, 1909; Cancer of the Esophagus from the Standpoint of Intrathoracic Surgery: A Report of Four Resections, Surg. Gynec. Obst. **15**:639, 1912.

130. Janeway, H. H., and Green, N. W.: Experimental Intrathoracic Esophageal Surgery, J. A. M. A. **53**:1975 (Dec. 11) 1909.

In 1909, Tiegel [131] also used a modification of the button for intestinal anastomosis with some success, employing surgical procedures similar to those of Janeway and Green. He performed this type of operation once on man. The patient died eleven hours afterward.

In 1918, Bircher [132] resected two carcinomas which involved the lower end of the esophagus and the cardiac part of the stomach. His technic was similar to that of Voelcker,[128] in 1908; he used the abdominal route and avoided opening the pleural cavity. In the first case, the esophagus was freed at its hiatus and easily drawn down above the upper limits of the tumor. This was then removed, the esophagus closed by ligature and the wound in the stomach closed, except for about 3 cm. near the greater curvature. Five long sutures were introduced into the wall of the esophagus, and an incision 2 cm. long was made on the anterior wall of the stomach about 5 cm. below the upper opening. Forceps were introduced through the lower opening in the stomach, passed through the upper opening and the long esophageal sutures seized. The esophagus was brought within the stomach through the upper opening by traction and made fast to the stomach after the manner of a Senn gastrostomy, three rows of sutures being used. A fourth row of sutures attached the stomach to the diaphragm all around the esophagus, thus completely covering it with peritoneum. The long esophageal sutures were cut, and the lower part of the opening in the stomach was used for a Kader type of gastrostomy. The patient, a woman, aged 63, was able to eat any kind of food one month after operation and survived for eighteen months. In the second case, Bircher used almost the same technic, except that he implanted the esophagus into the stomach after the manner of Witzel's gastrostomy. The patient died of cardiac insufficiency three days after the operation. At necropsy, the stomach was found adherent to the diaphragm. Bircher said that for primary union, operation should take place through the abdomen, and an attempt should be made to avoid the thorax entirely. Whereas Voelcker was satisfied with two layers of sutures for the implantation of the esophagus, Bircher used three, so that the esophagus was covered with peritoneum as much as possible.

In 1919, Bengolea [133] removed a carcinoma of the thoracic portion of the esophagus in a woman, aged 37, by the transpleural route, using a

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131. Tiegel, Max: Zur Chirurgie des Oesophagus, Beitr. z. klin. Chir. **65**:314, 1909; Die chirurgische Behandlung des Speiseröhrenkrebses ihr gegenwärtiger Stand und ihre Aussichten für die Zukunft, München. med. Wchnschr. **57**:896, 1910.

132. Bircher, Eugen: Operative Heilung eines Karzinomes, am Uebergang des Oesophagus in die Kardia, Cor.-Bl. f. schweiz. Aerzte. **48**:467, 1918.

133. Bengolea, A. J.: Radical Resection of the Oesophagus for Carcinoma, Surg. Gynec. Obst. **29**:413, 1919.

Torek incision. The stomach was brought up through the diaphragm and esophagogastrostomy performed with the aid of a wooden bobbin placed in the oral end of the esophagus, which was invaginated into an opening on the fundus of the stomach. Closed drainage was used in accordance with Kenyon's technic. This proved inefficient, and, the wound had to be reopened, when serosanguineous fluid, which later became purulent, was evacuated. The patient died thirty-seven days after the operation.

In 1920, Kirschner [52] used an abdominothoracic route to operate in two cases of carcinoma of the lower end of the esophagus also involving the cardiac part of the stomach. The incision began about midway between the xiphoid process and umbilicus, extended laterally to the left costal margin and from there along the seventh intercostal space. After dividing the diaphragm down to the esophageal hiatus, he freed and removed the tumor. He then mobilized the stomach according to his method, which has been described. The oral part of the esophagus was extracted through the neck, after the manner of Ach,[111] and brought downward under the skin of the chest. The mobilized stomach was then brought up onto the anterior thoracic wall subcutaneously, with the ultimate aim of joining the esophageal and gastric orifices by skin esophagoplasty, thus making a new artificial esophagus. The first patient died the day following operation, and the second survived five days. In the second case, the lower 3 cm. of the subcutaneous oral end of the esophagus necrosed, but the stomach was in good condition. Mediastinitis was present.

In 1922, Kümmell, Jr.,[134] introduced a new method for the operative treatment of carcinoma of the thoracic or cardiac portion of the esophagus. After freeing the esophagus in the neck and at the diaphragmatic hiatus, he mobilized the stomach after the manner of Kirschner. One index finger was inserted downward into the cervical wound along the esophagus and the other upward through the hiatus. Working with these fingers, he separated the esophageal wall from its surrounding mediastinal tissue until the two index fingers came in contact with one another, the esophagus being thus loosened in its bed. It was pulled upward until the cardia appeared in the cervical wound, so that the stomach now filled the mediastinum. The tumor was resected and esophagogastrostomy performed, the line of suture being extrathoracic and not to be replaced in the wound until it was known to hold. In this way Kümmell completed the immediate formation of a new esophagus in one stage; he believed that the stomach acts as a good tampon to stop bleeding from the esophageal bed. In spite of the fact that the

134. Kümmell, Hermann, Jr.: Operation des Oesophaguskarzinoms, Deutsche med. Wchnschr. **36**:1886, 1910; Ueber intrathorakale Oesophagusplastik, Beitr. z. klin. Chir. **126**:264, 1922.

five dogs and two patients operated on in this way died of rupture of the pleura with hematothorax within twenty-four hours of the operation, Kümmell was enthusiastic, and said that the advantages of his method lay in the avoidance of the larger mutilating operations; the extrathoracic opening and juncture of the stomach and the esophagus, with prevention of the dreaded lethal mediastinitis due to suture or button insufficiency; the relatively rapid completion in one stage, and the immediate formation of a useful esophagus. In his experiments on animals and in clinical cases, he did not notice a disturbance in the nutrition of the wall of the mobilized and displaced stomach.

In 1923, Miller and Andrus [54] performed intrathoracic esophagogastrostomy experimentally on dogs. They used the bulkhead suture of Halsted for the anastomosis. After the lower part of the esophagus had been resected and the cardiac stump inverted, the site on the stomach for the implantation of the esophagus was selected, and a circular area, about twice the size of the esophageal lumen, was outlined by an incision which passed through the serous and muscular coats. A temporary occluding ligature was obtained by threading a needle with strong silk and grasping the tissue in the bed of this incision at close intervals. The lumen of the esophagus was closed in a similar fashion at the upper limit of the proposed resection. Both the stomach and the esophagus were cut away just distal to the occluding ligatures; the resultant stumps were cauterized with cautery and phenol and brought into apposition by mattress sutures of fine silk. Just before the last two or three of these sutures were tied, the loop of each occluding ligature was drawn into plain view and cut and these threads pulled out; the lumen was thus reestablished. Care was taken to grasp the submucosa with the first sutures; then followed a row of sutures which grasped the muscular coats of the stomach and esophagus. The operation was performed eighteen times. Four dogs died within a few hours from shock and hemorrhage, and three other operations failed, two because of tension and one because of the occurrence of gangrene in the part of the gastric wall involved in the suture. All of the remaining eleven dogs showed an intact suture line and functioning anastomosis, despite the occurrence of death from infection, dilatation of the stomach and diaphragmatic hernia. Reference has been made to the work of these authors on the structure of the esophagus of human beings and the mobilization of the stomach. They concluded that resection and suture in situ of the esophagus were not beyond the bounds of possibility but rather offered definite grounds for hope.

In dealing with the resection of the lower part of the esophagus with subsequent esophagogastrostomy, Heuer, Andrus and Bell,[135] in 1925,

135. Heuer, G. J.; Andrus, W. D. W., and Bell, H. G.: The Experimental Transplantation of the Diaphragm as an Adjunct in the Treatment of Lesions of the Lower End of the Oesophagus, Ann. Surg. **81**:273, 1925.

sought to convert the procedure into an abdominal operation by the upward transplantation of the diaphragm, hoping in this way to avoid the well recognized danger of intraplantation of the diaphragm and to test the feasibility of the procedure, and later to perform intra-abdominal esophagogastrostomy after resection of the esophagus. In the first series of dogs, the thorax was entered on the left side, and the periphery of the diaphragm was detached from its costal attachment and sutured to the parietal pleura at a higher level. In the second series, these authors not only transplanted the left half of the diaphragm, but also divided it down to the esophageal hiatus, freed the lower part of the thoracic esophagus, and sutured the diaphragm to its wall at a higher level. In a third series, freeing the esophagus only at its hiatus accompanied the upward transplantation of the diaphragm. In the first series, good results were obtained. In the second, there was a mortality of about 30 per cent, the result of infection; postoperative vomiting was common, apparently due to constriction of the esophagus at its new hiatus. One case of diaphragmatic hernia occurred in this series. Two dogs comprised the third series; both recovered promptly from the operation without vomiting and were killed later. Diaphragmatic hernia was found in one case.

In six animals of the second and third series, intra-abdominal esophagogastrostomy was performed after resection of the lower part of the esophagus. The Halsted bulkhead type of suture was used as in the intrathoracic work of Miller and Andrus. An intercostal incision was made into the abdomen, and comment was made on the good exposure obtained and the fact that the operation was not difficult. The authors submitted a patient suffering from carcinoma of the lower end of the esophagus to this two-stage procedure. Although the history was only of two months' duration, the tumor was 7.5 cm. long and 5.5 cm. in diameter. Besides upward displacement of the diaphragm, the tumor was freed and the diaphragm sutured to the esophageal wall above it. The second stage was not undertaken, as the patient died forty-eight hours after the first operation. At necropsy, gangrene was found involving the proximal half of the growth and extending upward on the uninvolved esophagus to a point about 1 cm. above the new hiatus. At one point on the right anterolateral wall, perforation had occurred in the gangrenous area allowing leakage into the pleural and abdominal cavities. They concluded that it would be better to leave the freeing of the esophagus from its bed until the second stage.

In 1926, Fischer[136] introduced still another technic for the safe anastomosis of the esophagus and stomach intrathoracically. After

136. Fischer, Herman: Esophageal Implantation into Stomach After Intrathoracic Resection of the Esophagus for Carcinoma: A New Method, Arch. Surg. **12**:241 (Jan.) 1926.

opening the pleural cavity by Sauerbruch or Torek's incision, he performed left phrenicotomy; this operation, by abolishing the respiratory movements of the side of the diaphragm, relaxes that structure, making easier the subsequent fixation of the stomach to its cut edge and ensuring undisturbed healing of the anastomosis. To effect this, he cut a seromuscular quadrilateral flap from the upper part of the stomach with its base downward, and to the denuded submucosa he sutured the sides of the oral end of the esophagus, only its distal part entering the lumen of the stomach through a small incision in the submucosa, near the base of the flap. The flap was then sutured over the esophagus and broad Lembert sutures covering the flap finished the anastomosis. The suture which occludes the oral end of the esophagus is of plain catgut, which will be digested by the gastric juices in a few hours, and thus the esophageal lumen will be rendered patent. From experimental work done on the cadaver, Fischer has satisfied himself that his technic is feasible and not difficult.

In 1927, Gohrbandt [137] described an operation for carcinoma of the lower end of the esophagus somewhat similar to that of Kümmell [134] in that the mobilization of the viscus was carried out in the same way, namely, by the insertion of one forefinger down from the wound in the neck, and the other up through the diaphragmatic hiatus and by a circular and progressive motion eventually bringing about the meeting of the fingers near the level of the hilum. The esophagus was then pulled down and the tumor resected in the peritoneal cavity. A Babcock probe was then introduced through the neck along the side of the esophagus into the abdomen and firmly sutured to the distal part of the oral end. The probe was drawn up out of the wound in the neck, bringing the esophagus along with it. The esophagus was then transposed under the skin of the anterior thoracic wall. A portion of the stomach was drawn up under the skin for later plastic anastomosis with the antethoracic esophageal stump. The patient was to be nourished through a Witzel gastrostomy until the anastomosis was completed.

Gohrbandt reported six cases. In the first case, a carcinoma situated just above the cardia was resected intra-abdominally and esophagogastrostomy performed; the patient lived for six months after the operation and died of an intercurrent disease. By the tunneling method described, the author attempted the removal of five carcinomas. Of these, two proved to be inoperable; one patient died of pneumonia three days after the operation; in another the tumor perforated while being loosened, with a fatal result, and in a third case, death occurred on the ninth day following operation from a phlegmon of the antethoracic site of anastomosis of the stomach and esophagus.

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137. Gohrbandt: Zur Operation des intrathorakalen Oesophaguskarzinoms, Zentralbl. f. Chir. **54**:26, 1927.

Thoracic and Cardiac Portions (Transposition of the Oral End).—In 1898, Levy [138] devised an ingenious, although rather impracticable, method of removing the thoracic part of the esophagus in dogs. He first performed gastrostomy and afterward severed the esophagus in the neck, suturing the oral end to the skin. He next brought a thread that had been introduced into the aboral end of the divided esophagus through a stomach tube out of the gastrostomy opening. He closed the upper end of the lower part of the esophagus in the neck by tying it with the thread. By pulling slowly on the thread, he inverted the esophagus and gradually pulled it out through the gastrostomy opening. When the cardiac part appeared, he ligated and cut the stump, sliding it back into the stomach. One of the animals lived six weeks. Levy tried this method on the cadaver, but he did not succeed in pulling out all the esophagus as he had done in dogs, as the outer longitudinal muscle fibers separated and remained behind. Consequently, he concluded that the procedure was not possible in man.

Mikulicz,[139] in 1904, was the first to introduce antethoracic subcutaneous transposition of the oral end of the esophagus after resection of its upper thoracic part. After intrathoracic resection, both ends were inverted and the thorax closed. The oral end of the esophagus was then brought out through an incision at the anterior border of the left sternomastoid muscle. Mikulicz said that because of the loose attachment of the esophagus in the mediastinum he succeeded without difficulty. Then the bared esophageal stump was brought under the skin in front of the pectoralis major and its end fixed to the edges of a small transverse incision over the second intercostal space. The wound in the neck was closed tightly. It was later proposed to make a plastic juncture between the esophagostomy and a gastrostomy opening which, of course, had to be performed to provide the animal with nourishment temporarily.

In 1904, Kelling [140] also introduced a method of transposition of the oral end of a transected esophagus. He believed that the opening of the esophagus within the thorax was the chief factor of the high mortality consequent on intrapleural esophageal operations, since infection of the pleura or mediastinum was almost certain to occur. Therefore, he sought to operate aseptically in the pleural cavity and mediastinum by refraining from opening the esophagus here. He

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138. Levy, William: Versuche über die Resection der Speiseröhre, Arch. f. klin. Chir. **56**:839, 1898.

139. Mikulicz, von: Chirurgische Erfahrungen über die Sauerbruch'sche Kammer bei Unter- und Ueberdruck, Verhandl. d. deutsch. Gesellsch. f. Chir. **33**: 34, 1904.

140. Kelling, Georg: Zur Frage der intrathorakalen Operation der Speiseröhre, Zentralbl. f. Chir. **31**:609, 1904.

performed an intrathoracic operation and loosened the tumor from its surrounding tissues, closing the thorax immediately afterward. The abdomen was then opened and the esophagus freed from the diaphragm. The cardiac portion of the esophagus was divided and the distal end closed; in the oral end he placed a wooden cylinder, and after tying the esophagus around this, he enclosed the end in a rubber membrane. He now pulled on a thread which had previously been passed down the esophagus and fastened to the wooden cylinder. The latter was pulled up, drawing with it the esophagus which was pulled out through an incision in the neck and after resection of the tumor drawn through a tunnel under the skin of the chest, being sutured to the edges of a transverse incision in the skin. He performed a skin esophagoplasty between the esophagostomy and the gastrostomy openings, with poor results.

In 1910, Wendel [141] performed operations in two cases of thoracic esophageal carcinoma, in each case bringing one end of the resected esophagus into the thoracotomy wound with a view to a future plastic operation. In the first case, the carcinoma was at the height of the bifurcation of the trachea; after the esophagus had been cut through below the tumor, the aboral end was brought forward into the thoracotomy wound in the anterior axillary line and sutured in position. The oral end of the esophagus was brought upward through an incision in the neck after the preliminary freeing from its surrounding tissues, and the tumor was then resected extrapleurally. The esophagus was then stitched into the wound in the neck. Death occurred from bilateral pneumothorax nine hours after the operation. In the second case, the carcinoma was in the lowest part of the thoracic portion of the esophagus. After the esophagus was cut through above the tumor, the aboral end was closed and the oral end was brought forward and sutured into the thoracotomy wound. Through a laparatomy incision, the tumor was pulled down and extirpated together with part of the cardiac end of the stomach. The wound in the stomach was reduced in size to that of a gastrostomy opening and sutured into the abdominal wall. The patient survived the operation only twenty-four hours. Collapse of the left lung was found at necropsy.

In 1913, Ach [111] and Zaaijer [142] succeeded in removing a carcinoma of the cardiac portion of the stomach and esophagus. Torek [97] removed a carcinoma from the thoracic portion of the esophagus. Ach planned his operation so that the pleural cavity should not be opened, working

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141. Wendel, W.: Zur Chirurgie des Oesophagus, Arch. f. klin. Chir. **93**:311, 1910.

142. Zaaijer, J. H.: Erfolgreiche transpleurale Resektion eines Cardiacarcinoms, Beitr. z. klin. Chir. **83**:419, 1913.

only in the neck and abdomen; he decided to remove the upper portion of the esophagus by invagination. He performed the operation first on dogs and then on four patients. A long laparotomy incision was made parallel to the left costal margin. The cervical portion of the esophagus was then exposed and mobilized by blunt dissection. The costal margin was retracted well upward so that good exposure was obtained. The diaphragm around the esophageal hiatus was freed and the tumor pulled down, both vagi being cut. The esophagus was clamped above the tumor, and a ligature about 1 meter long was tied around the esophagus above the clamp. A second clamp was applied above the tumor and the esophagus divided between them. A long flexible steel rod with an eye in its end was passed down the esophagus until it came in contact with the ligated oral end. A suture was passed through the esophageal wall, and the eye of the rod and was left about 12 cm. long. The rod was carefully withdrawn; the suture, as it was pulled taut, inverted the walls of the esophagus. The whole esophageal tube was thus extracted until the lower invaginated end appeared in the cervical wound, when the extraction ceased. The long ligature was secured from the invaginated funnel and fixation suture through the eye of the sound cut by the anesthetist. By pulling on the ligature, the invaginated esophagus was evaginated through the cervical wound and drawn through a tunnel under the skin of the sternum to a small transverse incision through which it was brought onto the surface of the chest. The tumor was then resected, the wound in the stomach closed and gastrostomy performed. Ach reported three cases in which he had performed operations by this method. In his second and third cases, instead of performing gastrostomy, he brought up the distal part of the stomach remaining after resection on to the anterior thoracic wall and placed it subcutaneously, thus performing an inferior esophagoplasty. All three patients died within fourteen days. He also reported fifty-five operations on dogs, most of which were intrathoracic resections, with success in only three.

Later, Ach [143] reported a fourth case of carcinoma of the cardiac portions of the esophagus and stomach in which operation was performed by his combined cervical and abdominal technic. He succeeded in removing the tumor, but the patient died seventeen days after the operation from "insufficiency of the gastric fistula."

Zaaijer [144] followed a plan similar to that which had been used in 1911 in his case of "oesophagostomia thoracalis" and performed the

143. Ach, A.: Beitrag zur Oesophaguschirurgie, München. med. Wchnschr. **60**:1115, 1913.

144. Zaaijer, J. H.: Ueberdrücknarkose und experimentelle Ösophagus-resektion, Zentralbl. f. Chir. **38**:992, 1911; Oesophagostomia thoracalis, Beitr. z. klin. Chir. **77**:497, 1912.

operation in two stages. The first consisted of extensive subperiosteal resection of the lower six ribs on the left side, from the angle forward for about 10 cm. This caused sinking in of the wall of the chest, thereby rendering the esophagus and cardia much nearer the surface of the chest. After the patient had recovered from this operation, the second stage was undertaken. A long curved incision was employed, beginning in the hypochondrium below and extending upward and backward in the posterior axillary line as far as the lower angle of the scapula, and in this way laparothoracotomy was performed. The diaphragm was cut through down to the esophageal hiatus and there freed. The lower part of the esophagus was mobilized and brought, with the stomach, into the wound. Zaaijer next cut through the stomach below the tumor, closed it and returned it to the abdomen, and then sutured the diaphragm. The esophagus with the tumor at its lower end was brought out through the wound, and the parietal pleura was sutured to the wall of the esophagus about 4 cm. above the upper margin of the tumor. Then followed closure of the pleural and peritoneal cavities. The tumor was removed by cutting through the healthy esophagus above it with thermocautery after a few days. The distance between the thoracic esophagostomy opening and the gastrostomy opening was provisionally overcome by an apparatus so constructed that food could be taken by mouth. The patient left the hospital fourteen days after the second operation.

Torek,[97] too, preferred to perform extrapleural resection of the esophageal carcinoma in his case, in order to do away with leakage from the oral end after resection. He also decided to pay particular attention to the avoidance of rough handling of the vagi. The patient was a woman, aged 67, with a carcinoma of the thoracic portion of the esophagus just below the lower border of the transverse arch of the aorta. The thoracic incision ran the whole length of the seventh interspace and extended upward posteriorly; the seventh, sixth, fifth and fourth ribs were divided near their tubercles. On retraction good exposure was obtained. The tumor was fairly fixed, and there was some difficulty in separating it from the arch of the aorta and the left bronchus, the latter sustaining a longitudinal cut during the dissection requiring repair by silk suture, which acted satisfactorily. Torek then dissected the esophagus free from its attachments all the way up to the neck, divided it with cautery a safe distance below the carcinoma after double ligation, and brought out the oral end with its tumor through an incision in the neck at the anterior border of the left sternomastoid. Thus the danger of infection of the mediastinum and pleural cavity from leakage of the oral end of the esophagus was obviated. The remaining lower end was crushed, ligated and invaginated, and the thorax closed without drainage. The portion of the esophagus which

was hanging out of the neck was drawn through a tunnel under the skin between the wound in the neck and a transverse incision over the second intercostal space; it was then brought to the surface through this incision, the carcinoma cut off, and the fresh rim of the esophagus sutured to the edges of the transverse incision. The wound in the neck was then closed. The patient made a good recovery and was nourished through the gastrostomy tube until the eighth day, after which time the outer end of this tube was introduced into the esophagostomy opening for the purpose of allowing the patient to carry out mastication and deglutition in the normal manner. Soon afterward she was able to take all varieties of food which could be chewed into an almost fluid state. In 1925, Torek [145] published a follow-up report on this case, telling of the patient's happy state and freedom from recurrence, and a year later stated [146] that she had died of pneumonia at the age of 79, after having been in good health up to three days before death. The patient had lived more than twelve years after the operation. Torek's case thus takes its stand as being the most outstanding and impressive in thoracic esophageal surgery. It is the only case in which the results obtained through surgical procedures have definitely exceeded those obtained by palliative measures and those obtained in many cases of carcinoma of more accessible organs when treated surgically. Although it is well known that for one patient, for example, with gastric or mammary carcinoma who survives operation for as long as twelve years, there are many who, although less fortunate, will live for three, four or five years; never before or since Torek's operation have there been any such promising results from the surgical treatment of esophageal carcinoma.

Unger [147] performed the same operation as did Torek, and his patient died five days afterward.

In 1914, Baumgartner [148] operated on a man with carcinoma of the thoracic portion of the esophagus. The patient died six hours after the completion of the operation. Baumgartner employed a technic similar to that of Torek but with minor differences. He chose to operate on the right side, mainly because of the absence of the aorta

145. Torek, F.: Carcinoma of the Thoracic Portion of the Esophagus: Report of a Case in which Operation was Done Eleven Years Ago, Arch. Surg. **10**:353 (Jan.) 1925.

146. Torek, F.: Surgical Treatment of Carcinoma of Esophagus, Arch. Surg. **12**:232 (Jan.) 1926.

147. Unger, Ernst: Zur Chirurgie des Oesophagus im Thorax, Berl. klin. Wchnschr. **50**:2090, 1913; Zur Chirurgie des intrathorakalen Oesophaguscarcinoms, Arch. f. klin. Chir. **106**:31, 1915.

148. Baumgartner, Amédée: Extirpation de l'oesophage thoracique pour cancer à l'aide de la respiration artificielle, Presse méd. **1**:34, 1914.

and the ease with which the azygos vein can be dealt with. He not only cut ribs near their tubercles, but resected one of them to obtain better exposure. He finally resected the tumor intrathoracically before transposing the oral end of the esophagus subcutaneously. Necropsy showed that the right pleural cavity contained about 0.75 liter of bloody fluid; a vessel which could be said definitely to be the source of the hemorrhage was not found.

In 1915, Meyer [149] reported on further experience with resection of the thoracic portion of the esophagus for carcinoma in four cases. All of the patients died. In three cases, he planned to restore the continuity of the esophagus with the aid of an extrathoracic Beck-Jianu tube. In the other case, he performed the Torek operation. Meyer, commenting on drainage of the pleural cavity after operations on the esophagus, said that his experience had convinced him that when Torek closed the thoracic cavity without drainage he was favored with remarkable luck. Meyer believed that it is the surgeon's duty to drain the thorax immediately after the operation in all cases of resection of the esophagus for carcinoma.

In 1922, Hedblom [150] resected a carcinoma involving the lower end of the esophagus and cardiac part of the stomach. He employed Zaaijer's method with the modification of performing the thoracoplasty in three stages instead of in one stage as Zaaijer had done, resecting the fifth to the eleventh ribs from their angles to the costal cartilages. His incision for resection extended from a point to the left of the median line below the costal margin upward and backward to the level of the fourth rib in the midaxillary line. Through this he opened both peritoneal and pleural cavities, split the diaphragm down to the hiatus and, after mobilizing the lower end of the esophagus, removed its lower 4 cm. together with the cardiac part of the stomach. The stomach was sutured to the lower part of the wound below the diaphragm and the esophagus to the wound above that structure. A month after the resection the patient had gained several pounds and was taking soft food by mouth, the esophageal and gastric stomas being connected by tube.

In 1922, Levy [151] reported a series of operations performed on dogs in 1913 and 1914. He began to resect the cardiac portions of the

149. Meyer, Willy: Further Experience with Resection of Oesophagus for Carcinoma, Surg. Gynec. Obst. **20**:162, 1915; Extrathoracic and Intrathoracic Esophagoplasty in Connection with Resection of the Thoracic Portion of the Esophagus for Carcinoma, J. A. M. A. **62**:100 (Jan. 10) 1914.

150. Hedblom, C. A.: Combined Transpleural and Transperitoneal Resection of the Thoracic Oesophagus and the Cardia for Carcinoma, Surg. Gynec. Obst. **35**: 284, 1922.

151. Levy, William: Weitere Beiträge zur Resektion der Speiseröhre, Arch. f. klin. Chir. **119**:20, 1922.

esophagus and stomach by a two-stage operation, the first being extensive thoracoplasty for the purpose of collapsing the wall of the chest and thus bringing the esophagus nearer to the surface of the chest and facilitating its exposure. He treated the resected portion of the stomach and esophagus in the same manner as Zaaijer had done. In ten operations there were six successes; the four failures were due to empyema. He pointed out that in this operation the stomach can be brought up to any level required by the esophagus, as the diaphragm can be sutured to the wall of the chest at any desired height. Levy made a small plastic skin tube to connect the esophageal and gastric orifices.

In 1924, Lotheissen [152] reported ten cases of carcinoma of the thoracic portion of the esophagus in which Torek's methods of operating were used. With the exception of two patients whose lesions were inoperable and who lived one and three months respectively after operation, all died within a few hours. Necropsy showed variously mediastinitis, empyema or collapse of the lung.

In 1925, Eggers [98] successfully removed a carcinoma of the thoracic portion of the esophagus by Torek's technic. Both vagi were sharply divided without disturbing the patient's condition. He employed closed drainage, and on the first day about 200 cc. of serosanguineous fluid passed through the tube; about 50 cc. passed on the second and third days, after which the drainage ceased; the tube was removed on the fourth day. The lower portion of the oral end of the esophagus had to be removed on account of gangrene. Connection between the esophageal and gastric orifices was established by a rubber tube, as in Torek's case. The only further mention of this case which seems to have appeared in the literature was made by Torek,[146] who, in 1926, stated that the patient was then living and in good health more than a year after the operation. It is of interest that the patient was young (aged 38) and that the symptoms had existed for only six weeks.

Thoracic and Cardiac Portions (Esophagoplasty by Means of Skin or Fascia).—In 1917, Höfer and Kofler [153] described an original method of extrapleural resection of carcinoma of the thoracic portion of the esophagus with repair of the esophageal defect by skin esophagoplasty. Their work was done on the cadaver. They cut a triangular skin flap with a vertical base of 14 cm. and a length of 20 cm. The base was to the right of the vertebral column, and the flap extended over this onto the left thoracic wall. The flap was raised and reflected to the right. Then followed the removal of the portions of the right

152. Lotheissen, Georg: Zur Radikaloperation des Speiseröhrenkrebses, Arch. f. klin. Chir. **131**:200, 1924.

153. Höfer, Gustav, and Kofler, Karl: Studie über Resektion des thorakalen Oesophagus, München. med. Wchnschr. **2**:1097, 1917.

trapezius and underlying rhomboid muscles which were exposed by the reflection of the flap. The ribs exposed by this procedure were resected for 10 to 12 cm. subperiosteally, the intervening intercostal muscles cut away and the pleura and esophagus exposed. Several centimeters of the azygos vein was removed, the carcinoma freed from its attachments and the esophagus separated above and below the tumor sufficiently to allow the introduction of the skin flap under it. The apex of the flap was pulled to the left of the vertebral column as far as possible; the upper edge was brought forward on both sides of the esophagus and sutured in front; the lower edge was treated in the same manner, so that the esophagus lay in a trough of skin. The tumor bearing part of the esophagus was to be removed at a second operation, and the esophageal defect repaired by the plastic formation of a skin tube, the posterior wall of which had already been made. Höfer and Kofler stressed the importance of the exact localization of the tumor by the esophagoscope and radiography so that the flap may be outlined correctly. The right side is preferred because of the absence of the aorta. Muscle is not included in the flap, because it is prone to necrosis if separated for any length.

In 1921, Lilienthal,[154] unaware of the work of Höfer and Kofler, devised a similar operation and tested it on the cadaver as they had done, but he was able to apply it clinically with some success. Lilienthal used a rectangular flap, the upper border of which was the eighth interspace, the lower, the tenth rib, its outer limit the midaxillary line, and its base about 3.75 cm. from the vertebral column. Whereas Höfer and Kofler attacked the esophagus from the right side, Lilienthal did so from the left, giving as his reasons the importance of the aorta as a landmark, the greater distance from the important veins and thoracic duct, and the avoidance of the difficulty of freeing the pleural fold which crosses the median plane at this point. After freeing the esophagus, the skin flap was placed in position, lying between the esophagus and the right vagus (the left vagus was not seen), the cuticular surface next to the esophagus and the terminal end turned round it and held in position by a silk suture running from its tip to the inner part of the wall of the chest, the trough of skin thus formed to be completed into a tube by division of the pedicle later. Several days afterward the tumor was resected, and later the pedicle was divided and turned outward to meet the terminal end of the flap. The pedicle, however, showed a marked tendency to return to its normal position. Before

154. Lilienthal, Howard: Carcinoma of Thoracic Oesophagus Extrapleural Resection and Plastic: Description of an Original Method with Report of a Successful Case Without Gastrostomy, Ann. Surg. **74**:259, 1921; Carcinoma of the Thoracic Oesophagus: Final Notes and Post-Mortem Examination in the Case Reported in the Annals of Surgery, September, 1921, ibid. **76**:333, 1922.

healing finally took place by granulation, five months had elapsed since the first operation. Contraction at the upper mucocutaneous juncture necessitated the passage of sounds. The patient lived for eleven months after being dismissed from the hospital. A tracheo-esophageal fistula, caused by recurrence of the growth, and terminal pneumonia were the cause of death.

Lilienthal mentioned having on four occasions, explored the mediastinum for carcinoma of the esophagus; in every case, the tumor had extended beyond the wall of the viscus. Three of the patients died of mediastinitis through injury to the esophagus during attempts to isolate it. In the fourth case, the cause of death was unknown.

In 1921, Budde,[155] working on the cadaver with a view to replacement of the resected part of the esophagus, built a pedicled tube of skin, fascia and muscle around a glass rod. Part of the thoracic portion of the esophagus was then resected extrapleurally and the tube implanted between the cut ends.

In 1922, Allen [117] resected a small piece of the thoracic portion of the esophagus and repaired the defect with fascia lata. He performed seventeen one-stage operations, with uniformly fatal results. The cause of death was empyema and mediastinitis due to leakage from the esophagus. By his two-stage method of double fascial tubes with subsequent opening of the outer tube and resection of the inner tube and that portion of esophagus inclosed by it, he performed six operations, of which four were successful. Both failures were due to empyema and mediastinitis after the first stage before the esophagus was opened.

Later, in 1925, Allen [118] operated on the thoracic portion of the esophagus in dogs in a manner similar to that used on the cervical portion. He employed the two-stage operation to remove a section of the esophagus without actually opening its lumen at either operation, depending on the tying of ligatures, which were planted around the esophagus inside the fascial sleeve, to cause necrosis of that part of the viscus between the ligatures. In four such operations, he failed to secure sloughing in one. The other three were successful, but were followed by definite stenosis. He attempted this operation in a case of carcinoma of the thoracic portion of the esophagus, but the tumor proved to be inoperable.

Comment.—An effort has been made, by this comprehensive review of the literature, to give an idea of the wide extent to which esophageal surgery has been practiced for the removal of carcinoma, and to show that the reason it has not succeeded has not been due to the lack of either effort or ingenuity.

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155. Budde, Werner: Zur Frage des plastischen Ersatzes schleimhautbekleideter Röhren: I. Urethra virilis; II. Oesophagus, Deutsche Ztschr. f. Chir. **161**:1, 1921.

There are two aspects of carcinoma regarding which opinions are divergent: that of early diagnosis, and the virulence of the growth.

It is well known that exploratory operations show most carcinomas to be inoperable, and many surgeons maintain that earlier diagnosis would bring the majority of these neoplasms within the limits of operability. This opinion warrants investigation. It is noticeable in published reports of cases that patients with esophageal carcinoma rarely consult a physician at the onset of symptoms, but generally wait for months rather than weeks. Can anything be attained by the education of the laity in regard to the early symptoms of esophageal carcinoma, such as commencing difficulty in swallowing solid foods and perhaps a sense of substernal oppression or later the regurgitation of ropy mucus into the mouth, so that such patients may be seen, for example, within a week of commencement of symptoms? The answer to this question depends on two points: the actual cause of the symptoms and the virulence of the growth. With regard to the former, one can say the symptoms are due to mechanical obstruction only. This means that the growth, even when the earliest symptoms appear, must have extended sufficiently to produce obstruction. Unfortunately, carcinoma of the esophagus grows not only inward, encroaching on the lumen, but extends outward simultaneously into the surrounding tissues, laterally to involve the whole circumference and upward and downward. Carcinoma of the esophagus, therefore, will be without symptoms until it has reached considerable size and is firmly fixed to surrounding tissue, or until the contraction of fibrous tissue develops in an attempted natural cure.

The degree of malignancy is of the greatest significance. The belief that these growths are relatively benign and slow-growing has been handed down to us, based chiefly on the frequently reported inability of observers to demonstrate metastasis at necropsy; many present-day surgeons persist in holding this opinion. Abel,[3] for instance said that he intends to prove that carcinoma of the esophagus is a relatively benign, mild type of malignant growth. On the other hand, the opposite view is slowly gaining ground. Souttar,[156] from his clinical experience, expressed the belief that carcinoma of the esophagus is of high grade malignancy, and that it fails to produce widespread secondary deposits only because death occurs early. Just as long as this problem can be discussed only on clinical grounds, there will be divergence of opinion. Broders'[157] method of grading the malignancy of tumors, however, aids considerably in deciding the issue. According

156. Souttar, H. S.: Treatment of Carcinoma of the Oesophagus: Based on 100 Personal Cases and Eighteen Post-Mortem Reports, Brit. J. Surg. **15**:76, 1927.

157. Broders, A. C.: Squamous Epithelioma of the Lip: A Study of Five Hundred Thirty-Seven Cases, J. A. M. A. **74**:656 (March 6) 1920.

to the degree of differentiation of the cells, any carcinoma can be placed in one of four grades arranged in increasing order of malignancy; thus, mild, slow-growing tumors are graded 1 and the most malignant tumors are graded 4. This method, introduced in 1920, has received a fair trial, and in the hands of experts has proved to be reliable. I am indebted to Broders and Vinson [103] for allowing me to use their unpublished data concerning the malignancy of esophageal carcinoma. In a series of 220 cases of carcinoma of the esophagus observed at the Mayo Clinic, they found that more than 90 per cent of such tumors were graded 3 and 4, that is, they were of the most malignant types; cases graded 1 were not found. This is significant in considering the chance of success of surgical procedures, for it means that by the time a carcinoma has extended sufficiently to produce obstruction (at which time the earliest symptoms will appear) it will have spread beyond the limits of surgical removal, except perhaps in a few cases.

Other data compiled by Broders and Vinson strengthen this opinion and throw light on the question of metastasis. They found that in forty-two cases in which postmortem examinations were made, twenty-seven showed metastasis, whereas of the last fifteen cases of this series metastasis was found in fourteen.

Because of the anatomic structure and relationships of the esophagus, the highly malignant carcinomas of the organ, the frequent occurrence of metastasis, the danger of fatal infection and the mutilation which must always cause great shock, surgical removal of these tumors cannot be expected to be attended with any degree of success. Although a successful case may occasionally be reported, this will never justify routine surgical exploration and the attempted removal of esophageal carcinoma with its appalling mortality. The only operation which has attained even a small degree of success is extirpation of a cervical esophageal carcinoma with subsequent double flap skin esophagoplasty after the manner first introduced by von Hacker, or the single flap method of Lane [110] and Ach.[111]

Thus, it appears that only palliative measures can be applied as a routine in the treatment of patients with this disease. These include the use of radium, deep roentgen rays, diathermy, intubation, gastrostomy and dilatation. All of these methods have their advocates and their opponents, and a voluminous literature has accumulated concerning them. As this phase is nonsurgical, its discussion has been omitted as being outside the scope of the subject of this article.

DIVERTICULA

Despite the fact that the so-called esophageal (pulsion) diverticula have been proved definitely to be pharyngeal, their surgical treatment is always considered a branch of esophageal surgery. Because they are

not uncommon and because the results of their surgical treatment are highly satisfactory, it was felt that they should be considered here.

There are a few important contributions to the early literature concerning diverticula that are worthy of note. Bell,[158] in 1816, was the first to draw attention to their occurrence. He performed necropsy in a case in which there had been trouble with dysphagia during life and found a posteromedial pouch at the upper end of the esophagus. He likened the condition to the hernal protrusion of mucosa which occurs in the bladder in cases of urethral or prostatic obstruction. Later he suggested that the surgical treatment should consist in emptying the sac by the establishment of a fistula.

Rokitansky,[159] in 1840, was the first to draw attention to the occurrence of two types of divertucula and classified them from an etiologic standpoint into two groups: (1) those due to traction exerted on a portion of the esophageal wall from without, and (2) those due to pressure within. Those in the first group he called traction diverticula and those in the second pulsion or pressure diverticula. Since Zenker and von Ziemssen,[160] in 1877, reported on their study of twenty-seven postmortem specimens, and described the etiology, pathology, symptoms, etc., of the condition, little has been added to the knowledge of the disease except the advances in the surgical treatment. These authors stated that the radical cure of pulsion diverticula by surgical measures from without was one of vain hopes, yet they were hopeful that even this operation conducted on Lister's plan might some day be performed without danger. Such was the state of surgery fifty years ago. The monographs on diverticula by Starck,[161] in 1900, and Rosenthal,[162] in 1902, are worthy of mention as comprehensive studies on the subject.

Although Bell [158] surmised the pharyngeal origin of the large pulsion diverticula, and Zenker and Ziemssen proved it, for a long time it was commonly accepted that the diverticula originated in a small triangular area at the upper end of the esophagus posteriorly just below the inferior constrictor muscle of the pharynx where the divergence of the esophageal musculature caused a weak spot. Keith [163] and others, however, have definitely pricked the bubble of the Lainer-Hackermann triangle, as this area is called, and have proved beyond question that

158. Bell, Charles: Surgical Observations, New York, Longmans, Greene & Company, 1816, p. 64.

159. Rokitansky, C., quoted by many authors.

160. Zenker, F. A., and von Ziemssen, H.: Krankheiten des Oesophagus in Ziemssen: Handbuch der speciellen Pathologie, Leipzig, 1887, vol. 7, p. 1.

161. Starck, H.: Die Divertikel der Speiseröhre, Leipzig, 1900.

162. Rosenthal, Werner: Die Pulsions-divertikel des Schlundes: Anatomie, Statistik, Atiologie, Leipzig, Georg Thieme, 1902, p. 142.

163. Keith, Arthur: Diverticula of the Alimentary Tract of Congenital or of Obscure Origin, Brit. M. J. **1**:376, 1910.

these diverticula are formed by the evagination of the mucous membrane through the posterior pharyngeal wall between the upper and lower parts of the inferior constrictor muscle, the main function of the former being to seize the bolus of food and force it into the esophagus, while the latter acts as a sphincter to the upper orifice of that viscus. Such diverticula are, therefore, true sacculi.[164]

Traction diverticula are usually found on the anterior wall of the esophagus near the bifurcation of the trachea, and they usually originate from a localized adhesion of the esophageal wall to the surrounding parts, sometimes the result of inflammation of one of the bronchial glands. The walls of the diverticula consist of all the coats of the esophagus, and they are therefore true diverticula.[164] They rarely give rise to clinical symptoms, although occasionally they may become enlarged, the increase in size being due to the arrest of food in the diverticulum and the gradually increasing pressure resulting therefrom. Oekonomides [165] gave the name of "traction-pressure diverticulum" to this condition.

Sauerbruch [166] reported a case in which a traction diverticulum had ruptured into the lung, causing abscess and the formation of fistula which necessitated operation. Ordinarily, however, such diverticula do not require surgical intervention.

The several methods of choice in the surgical treatment of pulsion diverticula (sacculi) are: extirpation in one or two stages, invagination and diverticulopexy (sacculopexy). Apart from the local operative measures, however, the preoperative preparation is important and consists of thorough oral hygiene and the lavage of the sac with mild antiseptic solutions. Some surgeons recommend preliminary gastrostomy in elderly and debilitated patients.

The earliest recorded surgical assault on a pharyngeal diverticulum was that of Nicoladoni [167] in 1877. His procedure consisted in opening the sac and establishing a fistula, thus putting into practice Bell's suggestion. The patient died from pneumonia six days after the operation. Shortly afterward a few surgeons attempted to remove radically these protrusions by the one-stage method, the essentials of which are the exposure and separation of the sac and its removal by cutting through the neck. The surgical approach to a diverticulum is exactly the same as that employed in cervical esophagotomy, the incision usually being

164. Morison, Rutherford, and Saint, C. F. M.: An Introduction to Surgery, ed. 2, Bristol, John Wright & Sons, 1926, p. 354.

165. Oekonomides, G.: Ueber chronische Bronchialdrüsen-affectionen und ihre Folgen, Basle, F. Riehm, 1882, p. 71.

166. Sauerbruch, F.: Oesophagusdivertikel, Zentralbl.f.Chir. **54**:1508, 1927.

167. Nicoladoni, K.: Ein Beitrag zur operativen Behandlung der Oesophagusdivertikel, Wien. med. Wchnschr. **27**:605 and 654, 1877.

along the anterior border of one or the other sternomastoid muscle, usually the left, because the majority of these pouches protrude on that side. C. H. Mayo,[168] however, advocated incision in the line of the natural crease of the neck, one-third being behind the anterior border of the sternomastoid. The sac is exposed by dissecting deeply between the carotid sheath laterally and the trachea and thyroid gland medially. After it has been separated from the surrounding structures by gentle blunt dissection, it is severed through its neck, usually between clamps or ligatures. The treatment of the stump then remains a matter of choice, but ordinarily interrupted sutures inverting the mucous membrane are used and followed by a further line of suture through the musculature. Although this operation is apparently ideal from the technical standpoint, it has a disadvantage which, although sometimes overcome, may prove fatal. Because of the absence of a serous coat, the line of suture is relatively slow in healing, and so the possibility of leakage through the sutured pedicle must always be considered and a drain inserted. Leakage will cause infection which is likely to spread down the fascial planes of the neck into the mediastinum, with fatal results.

Niehans,[169] in 1884, was the first surgeon to perform a one-stage operation for the removal of a diverticulum. The patient had a goiter as well. Niehans first removed the goiter, and after fifteen days, the symptoms not being relieved, excised the diverticulum with thermocautery between two ligatures. The patient was fed by stomach tube for a few days, and on the eighth day drank milk which flowed out of the cervical wound. Hemorrhage from the superior thyroid artery caused death on the twenty-fourth day after the removal of the sac.

In 1892, von Bergmann[170] reported the first successful extirpation of a diverticulum (6 cm. long), although a fistula persisted for several months. Kocher[171] reported two cases in 1892. In both, operation was successful; although temporary fistula developed in one case, the wound in the other case healed by primary intention. In 1893, Dugge,[172] in reporting a fatal case in which operation was not performed, commented on the small number of cases reported; he succeeded in finding only twelve cases in the literature of the six years preceding

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168. Mayo, C. H.: Diagnosis and Surgical Treatment of Esophageal Diverticula: Report of Eight Cases, Ann. Surg. **51**:812, 1910.

169. Niehans, quoted by Girard: Cong. franç. de chir. **10**:392, 1896.

170. Von Bergmann, E.: Ueber den Oesophagusdivertikel und seine Behandlung, Arch. f. klin. Chir. **43**:1, 1892.

171. Kocher, Theodor: Das Oesophagusdivertikel und dessen Behandlung, Cor.-Bl. f. Schweiz. Aerzte **22**:233, 1892.

172. Dugge, Carl: Ein Fall von Oesophagus-Divertikel, München. med. Wchnschr. **40**:529, 1893.

1893. Since that time, the number reported has increased continually. In 1903, Butlin [173] reported eight cases in which he had operated during the preceding ten years. In 1910, Stetten [174] reviewed all the cases he could find in the literature up to that time, and his statistics throw some light on the results of surgical measures in this sphere. In a group of sixty patients, fifty were cured and ten died, a mortality of 16.6 per cent. In a group of forty-eight patients on whom the one-stage operation was performed, the mortality was 18.7 per cent.

In 1918, Judd [175] reported a series of 35 cases from the Mayo Clinic with only 2 deaths. Two years later [176] he reported an additional 17 cases with only 1 death, making 52 cases in all. In 1923, C. H. Mayo [177] stated that the total number of patients operated on at the clinic had reached 74 without further mortality. In 1921, Deis [178] noted 134 cases in the literature; in 88 of these, the one-stage operations had been performed with 10 deaths, a mortality of 11.3 per cent, which is below that reported by Stetton for similar cases. In 22 of the cases reviewed by Deis, the two-stage operation had been performed without deaths.

The two-stage method was introduced by Goldmann,[179] in 1909, its purpose being to minimize the danger of spreading infection along the fascial planes of the neck consequent on leakage from the diverticular pedicle. By this method the sac, after being freed, is brought out into the operative wound and left there for about two weeks, during which time granulations form and wall off the fascial planes of the neck. The sac is then removed and the neck sutured. Since its inception by Goldmann, the two-stage method has been widely adopted and also modified in different ways by various surgeons. Goldmann, after freeing the sac, tied the pedicle with a silk ligature, packed a tampon around the sac and closed the wound in the skin, leaving a small opening for the removal of the tampon. The tampon was removed and the sac cut off a few days later. A fistula formed and drained for two months. Deis [178] was of the opinion that allowing the necrotic

173. Butlin, H. T.: An Account of Eight Cases of "Pressure-Pouch" of the Oesophagus Removed by Operation, Brit. M. J. **2**:64, 1903.

174. Stetten, DeWitt: The Radical Extirpation of Pharyngo-Oesophageal Pressure Diverticula, Ann. Surg. **51**:300, 1910.

175. Judd, E. S.: Esophageal Diverticula, Surg. Gynec. Obst. **27**:135, 1918.

176. Judd, E. S.: Esophageal Diverticula, Arch. Surg. **1**:38 (July) 1920.

177. Mayo, C. H.: Treatment of Diverticulum of the Esophagus, Ann. Surg. **77**:267, 1923.

178. Deis, Kurt: Die Behandlung der Zenker'schen Pulsionsdivertikel der Speiseröhre, Beitr. z. klin. Chir. **123**:623, 1921.

179. Goldmann, E. E.: Die Zweizeitige Operation von Pulsionsdivertikeln der Speiseröhre, Beitr. z. klin. Chir. **61**:741, 1909.

sac to separate by itself after ligating its neck is a safe procedure. Von Beck [180] also recommended this method, and reported seven cases with five successes; two patients died from pneumonia. C. H. Mayo,[177] after delivering the sac into the wound, sutures its neck to the sternomastoid or to the platysma muscle with a few interrupted catgut sutures, and the wound in the neck is closed around the neck of the sac. Ten or twelve days later the sac is again freed, then excised and the opening in the esophagus and the wound in the neck closed. Judd [178] illustrated this method. Murphy [181] advocated twisting the sac, packing around it, and later amputating it with suture of the pedicle. Wilkie's [182] method offers still greater protection against the danger of cellulitis and mediastinitis. After the sac is freed, the margins of skin are sutured to its body. The second stage, performed several days later, consists of incising the base of the sac down to the submucous plane and separating the mucosa by blunt dissection for about 5 cm. from the surface of the skin. The free edges of the mucosa are then united by a roll-in suture of chromic catgut and further invaginated by interrupted sutures. The stump is allowed to retract and the wound in the skin is partially closed by sutures. Wilkie reported two cases; in the first case the wound was dry in less than three weeks, and in the second a small fistula persisted for about five weeks.

Although the two-stage method is the more popular, the one-stage method still has its advocates. In 1910, Stetten [174] declared that the method of Goldmann did not require serious consideration and reported a case of his own in which the patient left the hospital with the wound completely healed sixteen days after the one-stage operation. In 1922, Bensaude and Grégoire,[183] also expressed belief that the one-stage operation is best and that the two-stage operation means taking unnecessary precautions. C. H. Mayo,[177] however, stressed the advisability of the two-stage operation if a large pouch is present, particularly if it extends down into the thorax. Recent reports by Lahey,[184] and by Crile and Dinsmore [185] showed excellent results obtained by the two-stage method.

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180. Von Beck, quoted by König: Deutsche med. Wchnschr. **1**:719, 1922.

181. Murphy, J. B.: Diverticulum of Esophagus: Conservative Treatment, Surg. Clin. Chicago **5**:391, 1916.

182. Wilkie, D. P. D., and Hartley, J. N. J.: Pharyngeal Diverticulum and its Surgical Treatment, with a Record of Two Cases, Brit. J. Surg. **10**:81, 1922-1923.

183. Bensaude, R., and Grégoire: Diagnostic et traitement des diverticules oesophagiens, Arch. d. mal de l'app. digestif. **12**:145, 1922.

184. Lahey, F. H.: Oesophageal Diverticula, Boston M. & S. J. **188**:355, 1923.

185. Crile, G. W., and Dinsmore, Robert: Diverticula of the Esophagus, S. Clin. N. Amer. **4**:863, 1924.

In 1896, Girard [186] treated two patients successfully by obliterating the cavity of the sac by invagination. By invaginating the sac by purse-string sutures, repeated as many times as is deemed necessary, its cavity is obliterated without being opened. The inverted sac either atrophies or sloughs off. Although this operation has the advantage of eliminating every possibility of infection, its disadvantage is that the polypoid projection produced by the inversion of the sac may, if large enough, produce occlusion of the pharyngeal lumen. This, then, would seem to limit the operation to small sacculi. There remains the question of recurrence after this operation. In 1912, Waggett and Davis [187] reported a case in which the former had operated by Girard's method with apparent success. Ten months after the operation, the patient said that after sneezing violently he felt "something break" in his neck. A diagnosis of reexpansion of the invaginated sac was made and operation undertaken. It was found that the diverticulum had much the same appearance as before the first operation. Radical extirpation by the one-stage method was undertaken with success, the wound healing by first intention. Bevan,[188] however, operated on what was evidently a large sac, and if inversion by repeated purse-string suture had been carried out, it is probable that pharyngeal occlusion would have resulted. To overcome this difficulty he used purse-string sutures for the outer part of the sac, but he reefed the inner part with longitudinal sutures, leaving the sac compressed against its attachment. In a later article,[189] he described a modification of this method for use with a large diverticulum. He first cuts through the middle of the sac by clamp and cautery, and after removing the outer part invaginates the remaining inner part. Von Beck [180] also tried the invagination method, with success. Besides being adaptable to cases of small diverticula, it is also useful if the patient is old and debilitated.

Diverticulopexy appears to have found a definite place in surgical treatment for pharyngeal diverticulum. The procedure was first proposed by Schmid [190] in 1912, who, on the cadaver, fixed the bottom of the sac at a higher level than its neck, the sac not being opened. This

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186. Girard, C.: Du traitement des diverticules de l'oesophage, Cong. franç. de chir. **10**:392, 1896.

187. Waggett, E. B., and Davis, E. D.: A Case of Pharyngeal Diverticulum, Lancet **1**:786, 1912.

188. Bevan, A. D.: Pulsion Diverticulum of the Esophagus: Cure by the Sippy-Bevan Operation, Surg. Clin. Chicago **1**:449, 1917.

189. Bevan, A. D.: Diverticula of the Esophagus, J. A. M. A. **76**:285 (Jan. 29) 1921.

190. Schmid, H. H.: Vorschlag eines einfachen Operations-verfahrens zur Behandlung des Oesophagusdivertikels, Wien. klin. Wchnschr. **25**:487, 1912.

operation was first practiced on the living subject by Hill [191] in 1918. The sac was dissected free and the fundus stitched to the left side of the inferior constrictor muscle, with at least temporary relief of symptoms. König [192] fixed the sac to the hyoid bone with success.

In 1922, Van den Wildenberg [193] reported that he had had recourse to diverticulopexy with complete success seven times. In four cases, he performed only this operation. In the remaining three he used it as a first stage, excising the pouch afterward at periods varying from eight days to three months. The second operation proved to be much more simple than the first, as the sac was found at once and only a small incision was needed. Diverticulopexy is not a radical procedure and Van den Wildenberg advised its use only as the first operation of a two-stage procedure; he further stressed this point in a later communication [194] as a result of one case of recurrence after the operation. In one case, Hautant,[195] besides performing diverticulopexy, ligated the neck of the pouch, his object being to prevent the reflux of food into its cavity, notably in postoperative vomiting. Deglutition took its normal course at once. One might think that there would be danger of sepsis from decomposition in this closed cavity. Hautant's patient, however, had enjoyed excellent health for six months at the time of report.

In summarizing the present status of the surgical treatment of pharyngeal sacculi one might say that the two-stage method can be done with so little risk that it has been adopted practically universally. Van den Wildenberg [194] has introduced sacculopexy as the first stage in two-stage removal. Statistics show that the one-stage method, although ideal from the technical standpoint, means unnecessary risk.

Invagination and sacculopexy have the disadvantage of not being radical operations. The former, however, is well suited for small sacculi, and although large ones can be treated in this manner, this procedure is not likely to be preferred to extirpation. Sacculopexy, by its simplicity, the absence of the risk of sepsis and because of the results already attained by this method, seems likely to become a more popular operative procedure as time goes on. It would seem to be ideal for old and debilitated patients.

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191. Hill, William: Pharyngeal Pouch Treated by Diverticulopexy, Proc. Roy. Soc. Med. **11**: (Sect. Laryngol.) 60, 1918.

192. König, Fritz: Zur Operation des Oesophagusdivertikels, Deutsche med. Wchnschr. **1**:719, 1922.

193. Van den Wildenberg: Diverticules dans l'oesophage, Arch. franco-belges d. chir. **25**:526, 1922.

194. Van den Wildenberg: Quatre nouveaux cas des diverticules oesophagiens opérés et guéris, Ann. d. mal. de l'oreille, du larynx. **46**:222, 1927.

195. Hautant, A.: Diverticule de l'oesophage guéri par diverticulopexie, Ann. d. mal. de l'oreille, du larynx. **43**:1016, 1924.

EXPERIMENTAL INVESTIGATION

The object of the experimental work undertaken was to obtain if possible a successful method of suture for end-to-end anastomosis of the esophagus, at first after simple division, and, if this proved satisfactory, after resection.

The difficulties which beset the surgeon in operating on the esophagus have been discussed. They exist because of the unique anatomic structure and relationships of the viscus. In my earliest experiments on the anastomosis of the divided organ, I was particularly impressed with the poor nature of the blood supply. Fatal cellulitis and mediastinitis were the outcome, and necropsy showed not only sloughing of the cut ends of the esophagus constricted by the sutures, but discoloration of the mucous membrane for several centimeters above and below the level of division which corresponded to the length of the esophagus necessarily isolated for the performance of the operation. As these experimental operations had been carried out with the usual aseptic precautions, it was felt that the primary factor causing the ensuing fatal infections was not the contamination of the surrounding tissues with esophageal secretion at the time of operation, as many authors seem to believe, but the sloughing at the line of anastomosis due to constriction of its blood supply by the sutures, with resultant leakage of infective esophageal secretion.

This led me to investigate the blood supply to the esophagus in the dog. After several unsuccessful attempts with prussian blue and carmine gelatin injections, it was decided that the most satisfactory method would be the injection of a radiopaque medium. That used was a mixture of barium sulphate and gelatin, made up according to the directions given by Gross [196] as follows:

> Soak 300 Gm. of fine French gelatine for two hours in 1,200 cc. of distilled water. To this add 1,000 Gm. of finely powdered barium sulphate, 500 cc. of distilled water, and 2 Gm. of thymol. Heat over a water bath until the gelatine dissolves and stir until the whole mass becomes a homogeneous milky fluid. Filter through two layers of Victoria lawn.

The specimen for injection was obtained in a manner similar to that used by Demel [197] in his work on the blood supply to the human esophagus. A recently killed dog was used. A median line incision was made which extended from the chin to the pubis, the skin was reflected widely on each side and the sternum and chondral parts of the ribs removed. The tongue was severed from its attachments, the posterior

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196. Gross, Louis: The Blood Supply to the Heart in its Anatomical and Clinical Aspects, New York, Paul B. Hoeber, 1921, vol. 16, p. 171.

197. Demel, Rudolf: Die Gefässversorgung der Speiseröhre: Ein Beitrag zur Oesophaguschirurgie, Arch. f. klin. Chir. **128**:453, 1924.

pharyngeal wall cut through, and the whole of the cervical viscera removed. The ascending part of the aorta was cut between ligatures and the heart removed; each lung was removed by cutting through the hilum just distal to a ligature and through the pulmonary ligament. By the removal of the heart and both lungs, the vascular bed to be injected was considerably diminished in size. The parietal pleura was incised on both sides about 2.5 cm. from the vertebral column. The intercostal vessels were ligated and cut from above downward to the level of the diaphragm, which was then separated from its costal and vertebral attachments. The hepatic artery was ligated and cut and the gastrohepatic ligament divided; the first part of the duodenum was cut between ligatures; the splenic artery was ligated and cut close to the spleen, and the branches of the gastro-epiploic arteries descending into the greater omentum were ligated and the omentum divided. The superior mesenteric, inferior mesenteric and renal arteries were then ligated and cut; the lumbar branches of the aorta were dealt with in the same manner and the aorta itself was severed just above its bifurcation.

In this way a specimen was obtained consisting of the whole length of the esophagus, the trachea, stomach and diaphragm, together with all the arteries from which the esophagus receives its blood supply.

A cannula was tied into the lower end of the aorta and the vascular bed of the specimen was washed out thoroughly with water injected into the cannula by a syringe. In order to render the vascular bed water-tight it was necessary to ligate such arteries as the internal and external carotids, the subclavians, the vertebrals, the transverse cervical and scapular arteries, the internal mammary arteries and any others through which water was seen to escape during the washing process.

The specimen was now ready for injection and was placed in the dish containing hot water. The injection apparatus was rendered as air-tight as possible, and when the valve on top of the oxygen tank was opened, gas passed into the carboy. The pinchcock was opened slightly; the mercury in the limbs of the manometer immediately showed a difference of from 10 to 20 mm.; the effect of this pressure acting on the surface of the injection medium was to force the latter out of the bottle, into the rubber tube to be connected with the cannula in the specimen. Before this connection was made, however, the mixture of barium sulphate and gelatin was allowed to run out of the rubber tube, as otherwise the air contained in the tube would be forced into the specimen in front of the injection medium which would then be unable to fill the vascular bed completely. As soon as the connection was made, the medium began to flow into the aorta and its branches. The pinchcock was opened gradually until the mercury in the limbs of the manometer showed a difference in height of 200 mm.,

and the medium was seen to fill the finer branches of the vascular bed. This pressure was maintained for one hour.

The aorta was then ligated and the cannula withdrawn. The specimen was placed in 10 per cent solution of formaldehyde for twenty-four hours, at the end of which time the injected barium sulphate and gelatin had solidified and roentgenograms were taken. Figures 1 and 2 show specimens prepared by this method. Several other specimens were injected and photographs taken. One specimen after injection was cleared by the Spalteholz method which consists of dehydration by

Fig. 1.—Roentgenogram of injected specimen.

alcohol, and then immersion in benzene and synthetic oil of wintergreen. The specimen was first placed in 40 per cent alcohol and changed every two days into an alcohol of 10 per cent additional strength, ending with immersion in absolute alcohol for four or five days. Next the specimen was immersed in benzene for two days, after which it was placed in oil of wintergreen. Clearing commenced almost immediately and continued until fine arterial twigs could be seen clearly. Oil of wintergreen forms the medium in which such a cleared specimen may be mounted permanently.

Figures 3 to 9 represent only a small part of the material which was studied and which was found to show the following points of interest:

1. The roentgenograms showed the poverty of the blood supply to the esophagus. This is apparent when the small amount of injection medium capable of filling the arteries of the esophagus is contrasted with the large quantity necessary to fill those of the stomach.

2. The blood supply is segmental. Most of the arteries divide into ascending and descending branches, and those of one particular segment anastomose with the arteries supplying the segments above and below.

3. The anastomotic network between the arteries of adjacent segments is scanty.

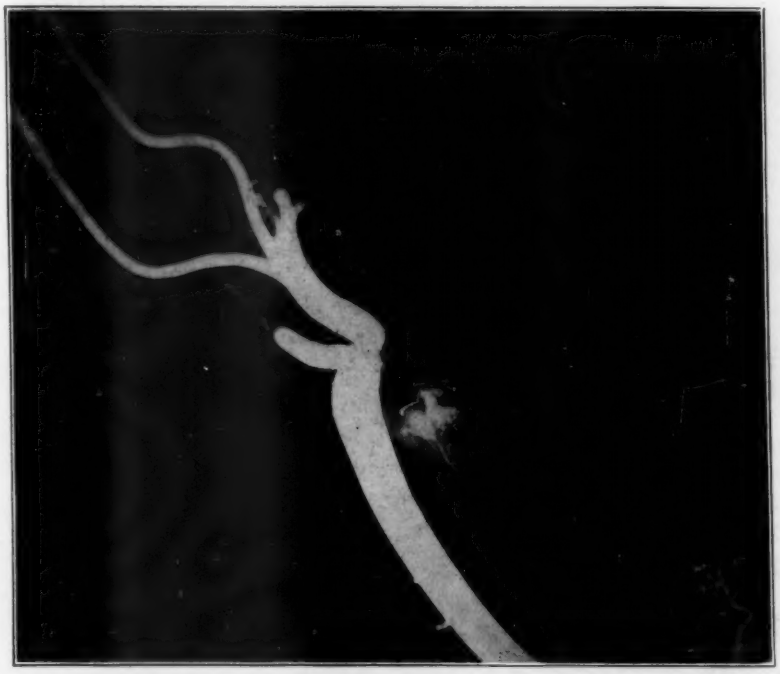

Fig. 2.—Roentgenogram of injected specimen. Cervical portion of trachea removed.

4. The arteries on entering the wall of the esophagus quickly pass into its submucous layer and there ramify. Microscopic sections of an esophagus, the arteries of which have been injected, show this layer to be by far the most vascular.

5. According to the distribution of its blood supply, the esophagus may be divided into the following segments: cervical, upper thoracic, middle thoracic, lower thoracic and abdominal.

The cervical segment is the most poorly supplied with blood of all the segments of the esophagus. Its upper and middle parts derive their blood supply from descending branches of the thyroid artery (this

artery corresponds to the superior thyroid artery in man and alone supplies the gland, there being no inferior thyroid artery in the dog). The lower part of this segment is the most vascular and receives its blood supply from ascending branches of the artery supplying the upper thoracic segment. Occasional twigs are given to the middle part of the cervical segment by the common carotid arteries.

In the esophagus of man, Demel found that three constant branches from the inferior thyroid artery supplied the lower part of the cervical segment, the first of these originating from the center of the ascending

Fig. 3.—Roentgenogram showing large-sized stomach tube in esophagus of dog (dog 1, table) twenty-two days after operation. The tube passed down without any difficulty.

portion, the second from the median bend and the third from the lower ascending portion close to the subclavian artery.

The upper thoracic segment is the part of the esophagus at the level of the innominate artery. From about the middle of the artery a constant tracheo-esophageal branch arises which soon divides into two branches, one supplying the esophagus and the other the trachea. The former divides into ascending and descending branches. Those which ascend anastomose with the descending branches from the thyroid artery

and with those from the common carotid when present. The descending branches anastomose with branches of the arteries which supply the middle thoracic segment. Demel did not find this tracheo-esophageal artery in his specimens from human subjects. Its place is taken apparently by the esophageal branches of the inferior thyroid.

The middle thoracic segment corresponds to the level of the bifurcation of the trachea. It receives its blood supply from two esophagotracheal arteries which were found to arise either from the second

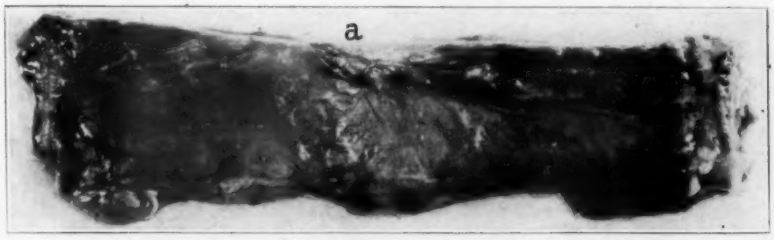

Fig. 4.—Cervical portion of esophagus removed from dog (dog 1) eighty-three days after operation; *a*, line of anastomosis.

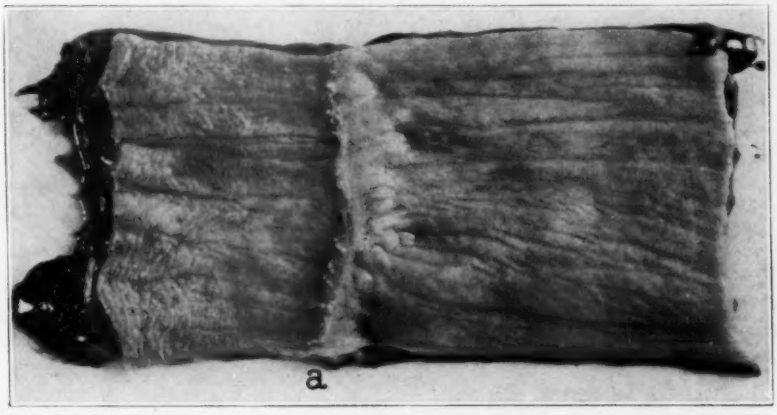

Fig. 5.—Mucosal surface of specimen shown in figure 4. The line of anastomosis, *a*, is seen as a pale transverse ridge over which the epithelium has grown completely; absence of stenosis (compare with figure 9).

intercostal artery near its origin or directly from the aorta at this level. Sometimes the arteries arise separately and at other times they spring from a common trunk only 2 or 3 mm. in length. They pass forward and downward and shortly before reaching the esophagus divide into two branches, an esophageal and a tracheal, the latter ascending to the bifurcation and the former entering the esophagus on its lateral aspects and then dividing into ascending and descending branches. The anasto-

mose above with twigs from the esophageal branch of the innominate artery and below with those from the arteries which supply the lower thoracic segment. This segment is the most vascular part of the canine esophagus. Demel found that it is also the most vascular part of the esophagus of man, which fact is of interest as the majority of esophageal carcinomas are found there.

The lower thoracic segment extends from just below the level of the bifurcation of the trachea to the diaphragm, and derives its blood supply from two arteries which arise from the third left intercostal artery near its origin or directly from the aorta at this level usually by a common trunk which is short although longer than that of the tracheo-esophageal arteries supplying the segment above. It divides into its two branches,

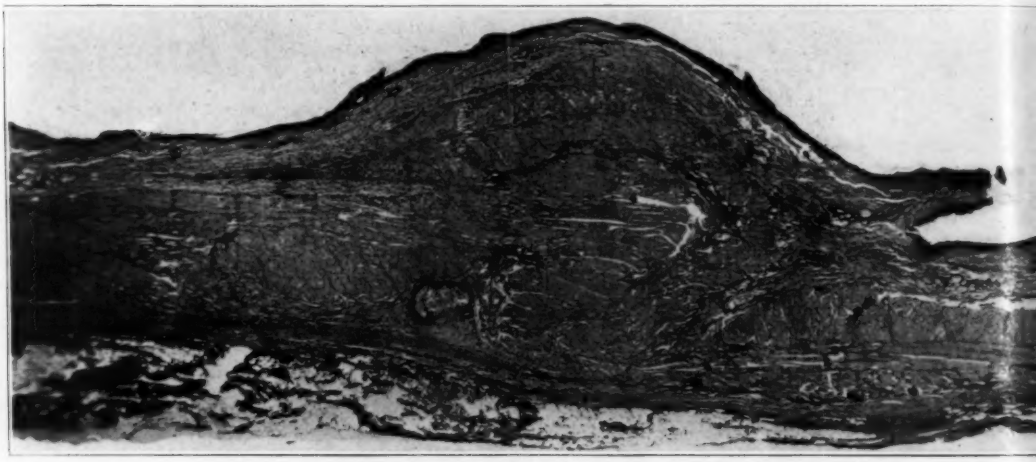

Fig. 6.—Longitudinal section through line of anastomosis of specimen in figures 4 and 5; complete epithelial overgrowth; the muscular coat is thickened at this point due to the method of suture; outside the muscular coat and covered by adventitia are the remains of a silk suture encapsulated by cellular fibrous tissue.

which pass downward, forward and to the left until they reach the lateral aspects of the esophagus where they enter it and divide into ascending and descending branches. To similar arteries in specimens from human subjects Demel gave the name "arteriores esophageae propriae." The lowest part of this segment has the poorest blood supply of the whole length of the thoracic portions of the esophagus.

In the arrangement of the tracheo-esophageal arteries and the arteriores propriae as described, slight variations may occur. Their mode of origin has been commented on. Sometimes one of the branches of the tracheo-esophageal trunk will supply only the esophagus. At other times one of the arteriores propriae will send an ascending branch

to the bifurcation of the trachea (fig. 1). Thus, there is apparently a compensatory arrangement in this group of arteries.

The abdominal segment is the part of the esophagus below the diaphragm. It is dependent for its blood supply on small ascending twigs which arise from the left gastric and left inferior phrenic arteries near their origins. They pass upward on the esophageal wall to anastomose with the descending twigs of the arteriores propriae.

Figure 7

Figure 8

Fig. 7.—Cervical portion of esophagus distended with water; specimen removed from dog (dog 2, table) seven days after operation. Absence of stenosis; *a*, oral end; *b*, line of anastomosis.

Fig. 8.—Mucosal surface of specimen shown in figure 7. Epithelial overgrowth has not taken place (compare with figure 5). Absence of stenosis; *a*, oral end; *b*, line of anastomosis.

These investigations show that the blood supply to the esophagus in the dog closely resembles that in man (as described in detail by Demel), the only difference being the replacement of the branches from the inferior thyroid artery by those from the tracheo-esophageal branch of the innominate artery.

The ability of a suture line to hold together the two cut ends of any viscus depends primarily on the conservation of a sufficient blood supply to the line of anastomosis. These studies clearly demonstrate the poverty of the blood supply to the esophagus and in consequence show that unless special care is exercised it would be an easy matter to produce enough constriction of the blood vessels by the sutures to cause sloughing of the two cut ends, which would result in the extravasation of the esophageal secretion with fatal infection.

Other factors that would appear to contribute to success are the smallness of the suture material and the putting at rest of the organ for a reasonable time after operation so that tension on the suture line is avoided. The structure of the esophageal wall must also be taken into consideration. The muscular coat forms poor material for suture as it will easily tear. The submucous layer, on the other hand, is strong and

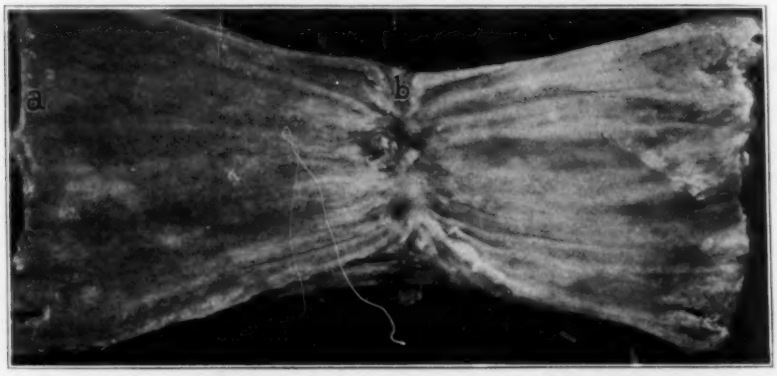

Fig. 9.—Mucosal surface of cervical portion of esophagus removed from dog (dog 5, table) thirty-six days after operation. Marked stenosis, with dilatation above the stricture. Epithelial continuity established over line of anastomosis; *a*, oral end; *b*, line of anastomosis.

its inclusion in the sutures is essential if the two cut ends are to remain in apposition. Aseptic technic with careful packing off of the divided esophagus from the surrounding tissues is a sine qua non. With these factors in mind, the following technic was devised for the end-to-end anastomosis of a divided esophagus:

The material used was Japanese blood vessel silk, no. 0 (which is finer and stronger than the thinnest catgut) on a fine straight needle, no. 12, about 1.25 cm. long.

The anastomosis was made by two rows of sutures. The inner row consisted of eight or nine interrupted inverting mattress sutures, spaced evenly around the circumference and passing through the whole thickness of the esophageal wall, thus including the strong submucous layer

in their grasp. The needle pierced the wall about 2 mm. from the cut edge, and each suture included about 2 mm. of the circumference in its grasp. Thus, while the blood supply to those parts of the esophageal wall caught in the sutures was constricted when they were tied, that of the remaining greater part of the circumference was unharmed. The outer row was a continuous suture passing only through the muscular coat and avoiding the submucosa where the vessels ramify. This outer row inverted the inner row and made the anastomosis water-tight.

It was decided first to attempt division at different levels of the esophagus, beginning with its cervical part, to ascertain the effect, if any, of the varying blood supply on the anastomosis. The operative procedure on this part of the esophagus was carried out as follows:

The anterior part of the neck was shaved and the animal anesthetized in the cabinet ordinarily used for this purpose at the Institute of Experimental Surgery and Pathology.[198] After the animal had been properly arranged on the operating table, the anesthetic was administered by the intratracheal method. The part shaved for operation was then treated with two coats of 2 per cent iodine in ether and draped with sterile towels. A median line incision was made which extended from the cricoid cartilage to the jugular notch. After hemostasis had been accomplished, sterile towels were clipped to the edges of the wound, thus excluding the skin from the area of operation. The incision was continued down to the trachea in the median line between the hyoid depressor muscles. The pretracheal fascia having been cut through, a finger was inserted backward along the left side of the trachea and hooked around the esophagus which was then brought up into the wound. The recurrent laryngeal nerves which are adherent to the esophagus were stripped off from it and the viscus isolated by blunt dissection. This method of approach to the esophagus is much easier than that between the sternomastoid muscle laterally and the hyoid depressor muscles medially. Enough of the esophagus was isolated to admit the application of two intestinal clamps between which the esophagus was to be divided, the required length being about 5 cm. These clamps were used only to occlude the lumen of the esophagus and so prevent the escape of secretion into the field of operation from either above or below. The pressure exerted by them was not sufficient to injure the blood supply. After the clamps were applied, the esophagus was thoroughly packed off in a manner similar to that used when gastro-enterostomy is to be performed. The part of the viscus between the clamps was then cut through by scalpel or straight scissors, and the ends turned upward and thoroughly wiped. The technic which has been described for end-to-end

198. Mann, F. C.: Anesthesia in Experimental Surgery, Am. J. Surg. **34:** (Anesthesia Supplement) 73, 1920.

anastomosis of the cut ends of the esophagus was then applied. Four or five interrupted inverting mattress sutures were inserted through the posterior half of the circumferences of the cut ends, the clamps were held close together to take tension off the sutures, which were then tied. The anterior halves of the circumferences were then drawn together by four or five similar sutures, each being tied before the next was inserted. The clamps were taken off at this stage. The second row, a continuous suture inverting the first, was begun at the center of the anterior part of the line of anastomosis. Traction toward the left was put on the short end while the suture was continued to the right. Each bite of the needle included as much of the esophageal muscular coat as seemed necessary to prevent the cutting through of the silk. When a point about half way around the circumference was reached, the needle was passed under the esophagus to the left side. Traction was then exerted on the short end toward the right and the suture continued from left to right until the starting point was again reached. In this way the entire circumference of the esophagus was sutured with ease. This method of performing the outer continuous suture is technically easier than putting in its posterior half before the introduction of the mattress sutures, as in gastro-enterostomy.

The esophagus was then replaced in its bed; the hyoid depressor and sternomastoid muscles fell into place; three or four interrupted catgut sutures were used to draw together the deep cervical fascia, and the skin was closed by a continuous suture of buttonhole-twist thread. Hemorrhage during the operation was not great.

The postoperative treatment is of great importance in the success of the operation. It consisted in placing the esophagus at rest for seven days by not giving any food or water by mouth during this period. Water balance and nutrition were maintained by 10 per cent dextrose solution in physiologic solution of sodium chloride administered intravenously in quantities varying from 200 to 350 cc. each day, according to the weight of the dog. At the end of this time the animal was allowed a mixture of milk and syrup for another period of seven days, after which ordinary food was given.

I performed six operations by this method on the cervical portion of the esophagus at different levels (table). Stricture occurred in two of the animals, probably because too much of the circumference of the esophageal wall was grasped by some or all of the mattress sutures, an imperfection in technic which can be remedied with care.

In only one of the six experiments did infection supervene. In the remaining five, the blood supply to the line of anastomosis was conserved sufficiently to prevent sloughing.

In the experiment in which sloughing of part of the line of anastomosis occurred, the operation was performed on the most vascular (lower) region of the cervical part of the esophagus; since a successful operation was performed later in the same region, the failure can be attributed only to faulty technic.

Four of the operations in which sloughing did not occur were performed on the least vascular (upper and middle) regions of the cervical part of the esophagus.

Results of the Division of the Suture of the Cervical Portion of the Esophagus

Dog	Date of Operation	Level of Division of Cervical Portion of Esophagus	Results: Infection	Results: Stenosis	Comment
1	12/ 6/27	Middle	—	—	Animal in good health to time of death (2/27/28), eighty-four days after operation; large sized stomach tube passed down esophagus without difficulty twenty-two days after operation
2	12/16/27	Upper	—	—	The plethysmograph had been applied to the spleen previously; the animal died suddenly seven days after operation; necropsy did not reveal the cause of death, a few adhesions were found around the esophagus at a level of the line of anastomosis, stenosis was absent
3	12/16/27	Lower	+		At operation this part of the cervical portion of the esophagus was found to be noticeably more vascular than the upper and middle parts (in agreement with observations in investigation of the blood supply to the esophagus); swelling of the neck fifth day after operation; 150 cc. of foul-smelling pus evacuated; animal died the seventh day after operation; necropsy showed sloughing of the anterior half of the line of anastomosis, posterior half intact, infection of the neck remarkably localized, in spite of low level of site of operation mediastinitis was not found
4	12/20/27	Lower	—	—	Animal alive and in good health; no dysphagia
5	12/21/27	Middle	—	+	Animal swallowed only fluids up to time of death, thirty-six days after operation; necropsy showed bilateral bronchopneumonia (? aspiration), marked stenosis and dilatation above stricture
6	12/21/27	Upper	—	+	Animal alive and well nourished, but swallowing fluids only

The results of these operations show that this method of suture allows for a supply of blood to the line of anastomosis plentiful enough to prevent sloughing and ensure union, even when the esophagus is divided in the least vascular regions of its cervical part.

Further experimental surgery along these lines, which will include resection of the cervical portion of the esophagus, together with division and resection of its thoracic portion, is being carried out.

SUMMARY

An outline is given of the development of surgery of the esophagus with a comprehensive survey of the literature on the subject up to the end of 1927.

The problems which have rendered surgical procedures in this sphere so difficult and which still remain to be overcome have been discussed.

They lie in the anatomic structure and relationship of the esophagus and in the risk of fatal infection of the pleura and the cellular tissue of the neck and mediastinum.

The numerous operations devised and performed for the extirpation of esophageal carcinoma have resulted in an appalling mortality.

It is pointed out that such tumors are highly malignant, that they metastasize readily, and that by the time they give rise to symptoms they usually have spread beyond the limits of surgical removal.

The various methods used for the plastic formation of a new esophagus in cases of benign cicatrical stricture believed to be impermeable are described. There is a mortality of 20 per cent in the cases reported in the literature; in addition, several operations are necessary and they require months for completion, and completion is by no means assured. These reasons render plastic operations undesirable procedures, to be avoided by early and adequate dilation and by impressing on the patient the necessity for further dilation at stated intervals.

It would seem, too, that plastic operations have been undertaken unjustifiably in many cases, the inability to pass the smallest sound being taken as the indication of impermeability. In nearly all such cases, however, a swallowed silk thread can worm its way through the stricture and then be used as a guide for sounds.

Pharyngeal diverticula are considered to be true sacculi and traction pouches to be true diverticula. The latter rarely require surgical treatment. The results of removal of pharyngeal sacculi by the two-stage method show that it is associated with lower mortality than the one-stage operation, and in consequence is practiced more commonly.

A method of suture which has given satisfactory results is described for the end-to-end anastomosis of a divided esophagus. The suitability of this method as a means of anastomosing the two cut ends of an esophagus after a portion of it has been resected is being investigated.

A NEW ABDOMINAL INCISION*

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The type of incision employed is one of the most important factors in the ultimate results obtained in operations on the abdomen. Sir Barkley Moynihan, in his chapter on abdominal incisions, stated that if the incision is improperly made by the free division of muscular fibers or a wilful and unnecessary severing of nerve trunks a weakened area is left in the abdominal wall, which may cause the patient distress of even greater severity than did the condition which primarily necessitated the operation. It would seem that the qualifications which should commend an abdominal incision are: that it give adequate exposure, disturb a minimum number of nerve and muscular fibers and be so placed that closure is simple, and that a minimum number of postoperative hernias follow its use.

I feel that there have been too many postoperative hernias following midline incisions or long incisions of the right rectus muscle and that a change from the old routine incision of the upper part of the abdomen should be made. I believe that the incision which I wish to present may be closed with less tension on the edges of the wound, will cut no muscles and will disturb few nerves; these are factors which should produce fewer postoperative adhesions, less abdominal pain and fewer postoperative hernias.

My experience again would lead me to believe that there are a large number of weak scars of the upper part of the abdomen following all types of incisions of the upper part of the abdomen now in use. Sloan's [1] report of weakened abdominal walls in 80 per cent of his cases coincides with my experience. In many instances there was no hernia but the abdominal wall was so thin that the constant wear and tear of a number of years, plus any slight strain, might be followed by a definite hernia. Observers, from Abel [2] in 1899 to the present time, have reported from 2 to 8.9 per cent of postoperative hernias. These percentages must be based on short postoperative periods of observation. My statistics would lead one to believe that the percentages, when based on five year periods of postoperative observation, are much higher.

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* Submitted for publication, March 16, 1929.

1. Sloan, G. A.: A New Upper Abdominal Incision, Surg. Gynec. Obst. **45**:678 (Nov.) 1927.

2. Abel: Progressive Medicine, 1899.

The rule that the frequency of hernia increases in proportion to the square of the length of the incision does not indicate as great incidence in the long incision as really exists. In the olden days, when drainage of the gallbladder was done more frequently than now, one frequently saw a short incision, approximately 3 inches (7.6 cm.) in length. One did not see many hernias or weak scars among these patients, but at the present time, when cholecystectomy plus appendectomy is in vogue, a great number of hernias occur in the long straight incisions, usually a little to one side of the rectus muscle.

The nerve supply of the rectus muscle is so situated that splitting the muscle for any distance will sever the nerve fibers and leave the inner side of the rectus devoid of nerve supply. In most of the cases in which a wide vertical splitting of the rectus fibers has been performed, atrophy of the inner side of the muscle occurs, owing to the cutting of nerves and to the dissociation of muscles and nerves at the time of the operation. One was at a loss to understand, at first, why these patients left the hospital with a fairly firm wound, and, as time passed, subsequent observations revealed a progressive thinning of the wound until a hernia developed or became imminent. Now it is realized that these developments were the result of muscle atrophy. This realization encouraged the effort to refrain from splitting the muscles if possible, and thus to conserve the nerve supply.

As Moschcowitz [3] stated:

> The rectus muscle is attached only anteriorly to the sheath and even here only at the three so-called lineae transversae, while its attachment to the posterior sheath is very loose and readily broken up. The lineae transversae, before mentioned, do not penetrate the entire thickness of the muscle but merely the anterior third or half.

On investigation I found these statements to be "anatomic facts," and thus I obtained the idea of rolling the muscles away from the posterior sheath, leaving it attached in its outer two-thirds to the anterior sheath, as will be described later in a drawing.

In addition, interesting investigations have been made by Professor Stopford and Mr. A. H. Southam,[4] who describe them as follows:

> We first examined the results of the incision passing through the outer third of the rectus muscle, splitting the fibers, and where two, or often more, nerves had been divided. This incision is easily and rapidly made and gives good access to most of the abdominal viscera. We found there was a very definite sensory loss, as shown by anesthesia and analgesia in the strip of skin between the scar and the

3. Moschcowitz, A. U.: Transverse Incisions in the Upper Abdomen, Ann. Surg. **64**:268, 1916.

4. Southam, A. H.: A Comparative Study of Abdominal Incisions, Brit. M. J. **1**:513 (March 22) 1924.

lineae alba. After about fifteen months, however, the sensory loss becomes negligible, as far as ordinary testing can determine, probably owing to regeneration of nerve fibers.

In all these cases there was a marked loss of function of that part of the rectus muscle lying between the point where the fibers were split and the midline. This may be fairly extensive or confined to one segment of the muscle, depending upon how many nerves have been divided. It is present from the outset and persists for a considerable period. In a few cases there was a slight bulge when coughing but for the most part the loss of muscle function could only be detected when the patient raised the head and shoulders from the couch. The functional results from the patient's point of view were excellent, and after secure suture and healing by first intention, no disability was apparent from the abdominal scar.

We next followed up the results obtained by the paramedian or rectus slide incision with outward displacement of the muscle and its nerves. In these cases, for some reason not readily explained, the sensory loss is insignificant from the start. We found that in this group the rectus muscle on the side of the scar functions normally throughout, and there is no weakness discoverable after this operation.

Sloan [1] has given some interesting and instructive information on the subject of vertical and lateral tension in an abdominal incision. By measuring the tension with spring scales attached to several forceps with lateral, transverse and "L"-shaped incisions, he found that the amount of tension increases approximately in proportion to the square of the length of the incision. In an incision 3 inches long, with the patient lightly anesthetized, there is about 30 pounds (13.6 Kg.) and in a 5 inch (12.7 cm.) incision there is about 80 pounds, (36.3 Kg.) tension. Another interesting point is that there is about thirty times as much tension from side to side on a longitudinal incision as there is from above and below on a transverse incision. The tension of the transverse incision can be lessened by a suitable posture, which has been suggested by Farr, in operating with the patient under local anesthesia.

I have found that the tension depends somewhat on the musculature of the abdominal wall. In a small woman with a thin abdominal wall, it is rarely possible to get more than from a 15 to a 20 pound (6.8 to 9 Kg.) pull on the scales when she is lightly anesthetized, while on a muscular man I have seen the scales go up as high as from 50 to 60 pounds (22.7 to 27.2 Kg.), approximating a 6 inch (15.24 cm.) incision during the time he was straining.

As to the frequency of postoperative adhesions, it cannot be stated correctly that one incision has any advantage over another, because many adhesions are due to causes far removed from the type of abdominal incision and the method of closure. I have noticed, however, that in most cases in which there was a straight, long, weak incision, or in which there was evidence of a hernia, adhesions to the parietal peritoneum were present in close proximity to the incision. From these

observations, it would seem that a strong firm scar is of primary importance in the prevention of postoperative parietal adhesions.

I shall describe a longitudinal and transverse incision that has been developed in the clinic within the past two years. It has been used forty-six times and, excepting one case in which the patient had a severe bronchopenumonia and coughed incessantly for days, has given uniform satisfaction. In this one case there was a slight separation of the transverse suture line, which was resutured immediately with a satisfactory result. This incision is based on the principle of the Kammerer incision, that of displacing the rectus muscles outward, and of the Mayo operation for the relief of umbilical hernia.

OPERATIVE PROCEDURE

A description of this incision follows:

Step 1: The incision is begun just to the left and below the ensiform cartilage. It is carried downward through the skin and fat to the median of the fascia covering the left rectus muscle. The incision is lengthened downward along the rectus muscle to within 2 or 3 cm. of the umbilicus; then it is carried straight across the midline to the right rectus muscle and downward along that muscle from 4 to 6 cm.

Step 2: The anterior surface of the left rectus muscle is cleared of fat. The fascia is also cleared well in the transverse and right rectus incisions.

Step 3: The fascia on the inner third of the left rectus muscle is split the length of the incision. A transverse incision is then made from one rectus muscle to the other. The fascia on the inner one third of the right rectus muscle is then opened.

Step 4: The muscles are rolled outward and the peritoneum opened behind the left rectus muscle. A transverse incision through the peritoneum just above the umbilicus completes the incision. This gives ample exposure for any operation in the upper part of the abdomen and allows the operator to reach and remove a retrocecal appendix in the lower right quadrant.

The following is the method of closure: The patient is placed in a flexed position. The transverse incision is first closed before the peritoneum is sutured. The suture is made after the manner of the Mayo repair of umbilical hernia, imbricating the upper with the lower flap securely with from two to three mattress sutures. The approximation of this part of the wound is facilitated by the flexed posture that has been advocated by Farr. The peritoneum of the upper part of the wound is then closed separately. The muscles are allowed to drop back in their sheaths and the aponeuroses are sutured in the usual manner.

CONCLUSIONS

A new abdominal incision is described for which the following advantages are claimed: The exposure is greater than in any incision that I have ever tried. It is easy of closure. It is a combination of a longitudinal and a transverse incision, allowing the wear and tear of years of tension on a scar line to fall on both of the recti muscles

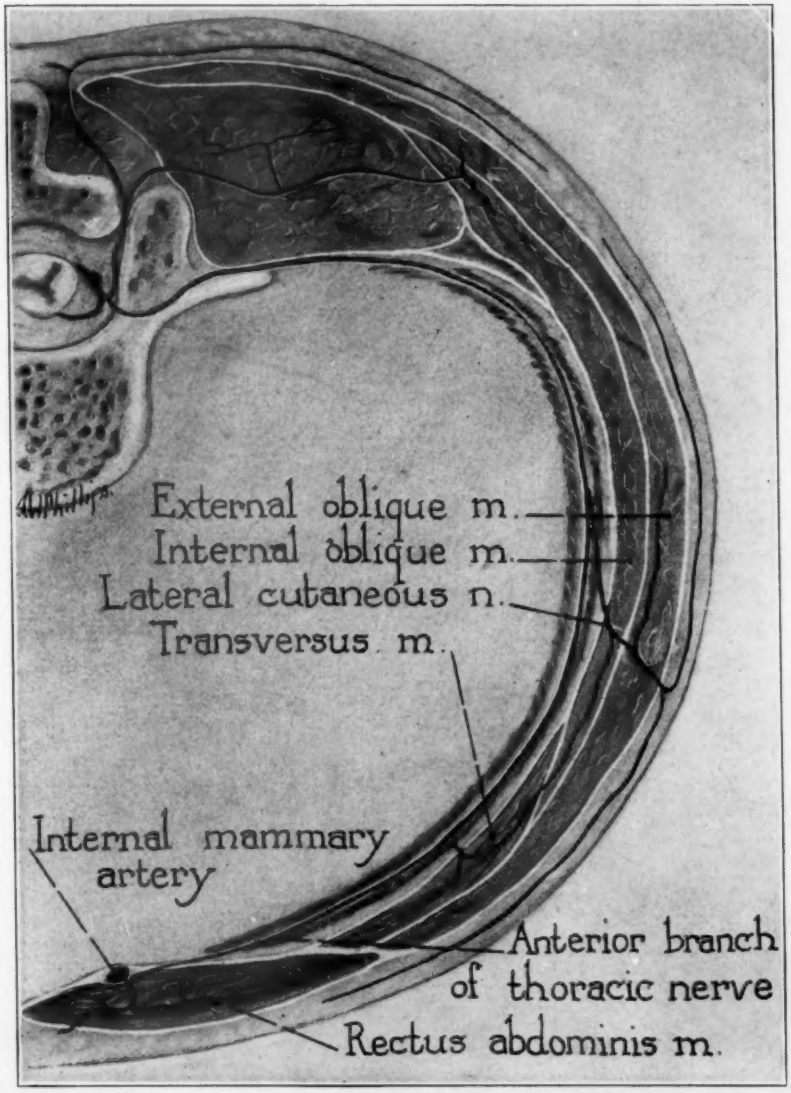

Fig. 1.—Section through the lower portion of the costal arch, demonstrating the nerve supply to the rectus abdominis muscle.

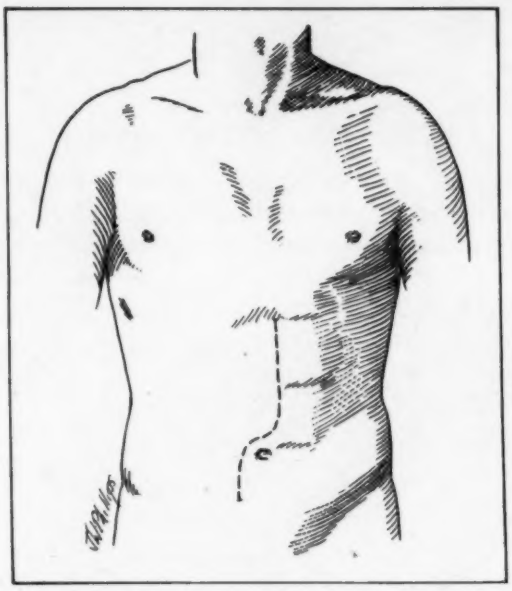

Fig. 2.—The dotted lines indicate where the incision is to be made.

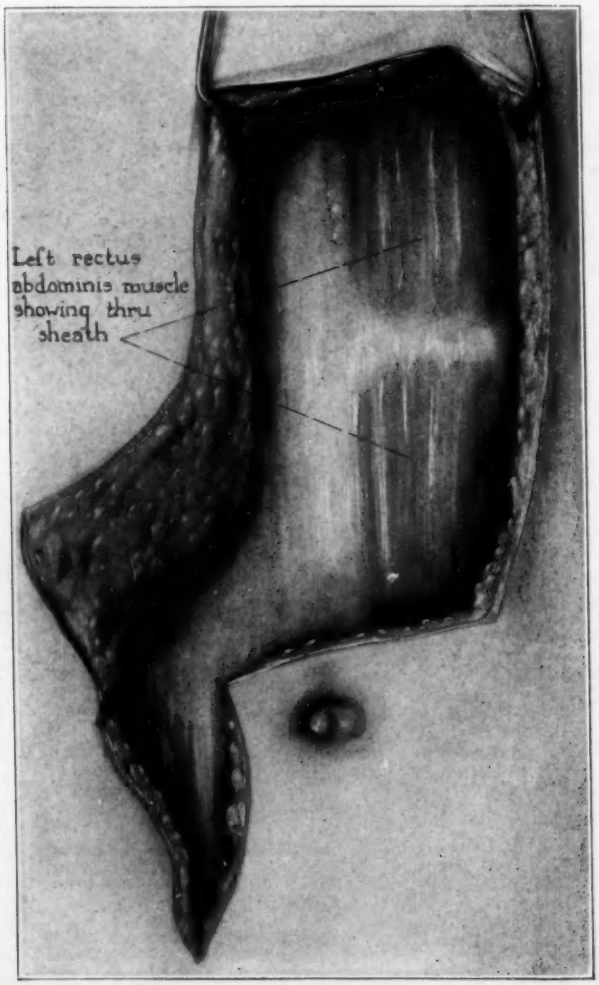

Fig. 3.—Superficial dissection, showing the right rectus muscle and the linae transversae in the upper part of the wound, and the sheath of the right rectus in the lower part of the wound.

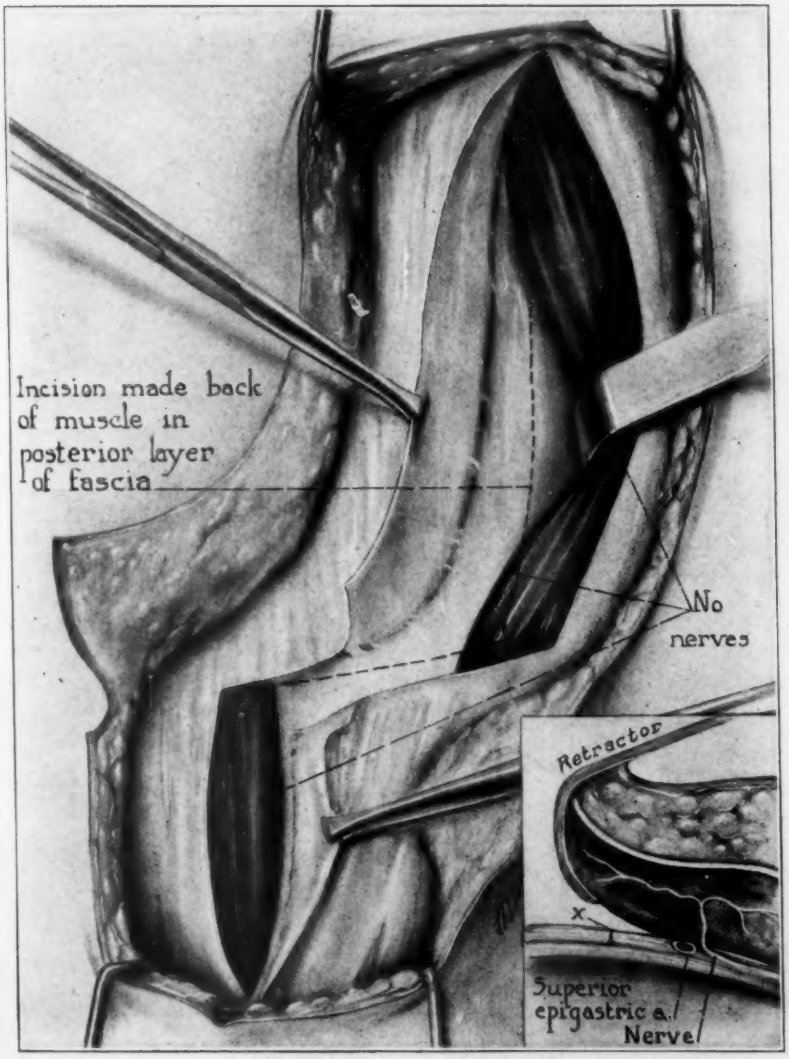

Fig. 4.—The anterior sheath of the rectus muscle is severed to just above the umbilicus, and the left rectus is retracted to the outer side. The diagnosis is made through this upper incision when the operator decides if the incision should be extended to a transverse and right rectus. The dotted line indicates the complete incision. In the insert, a section is shown with the muscle retracted. *X* indicates the position of the incision through the posterior sheath.

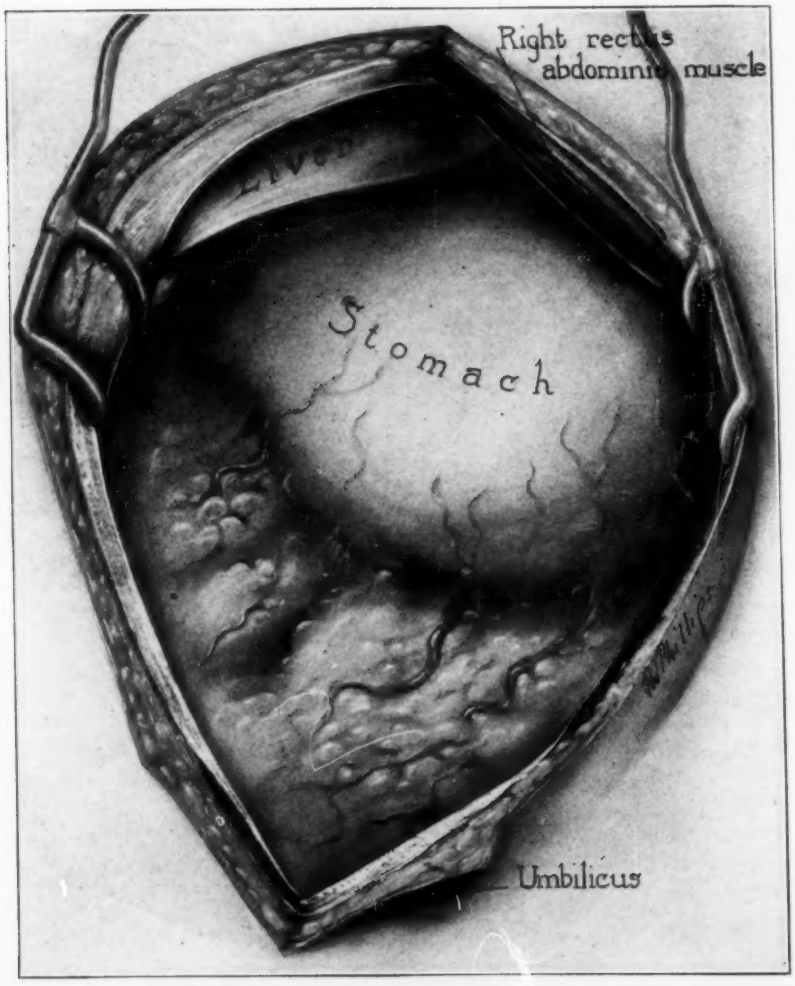

Fig. 5.—Demonstration of the exposure obtained.

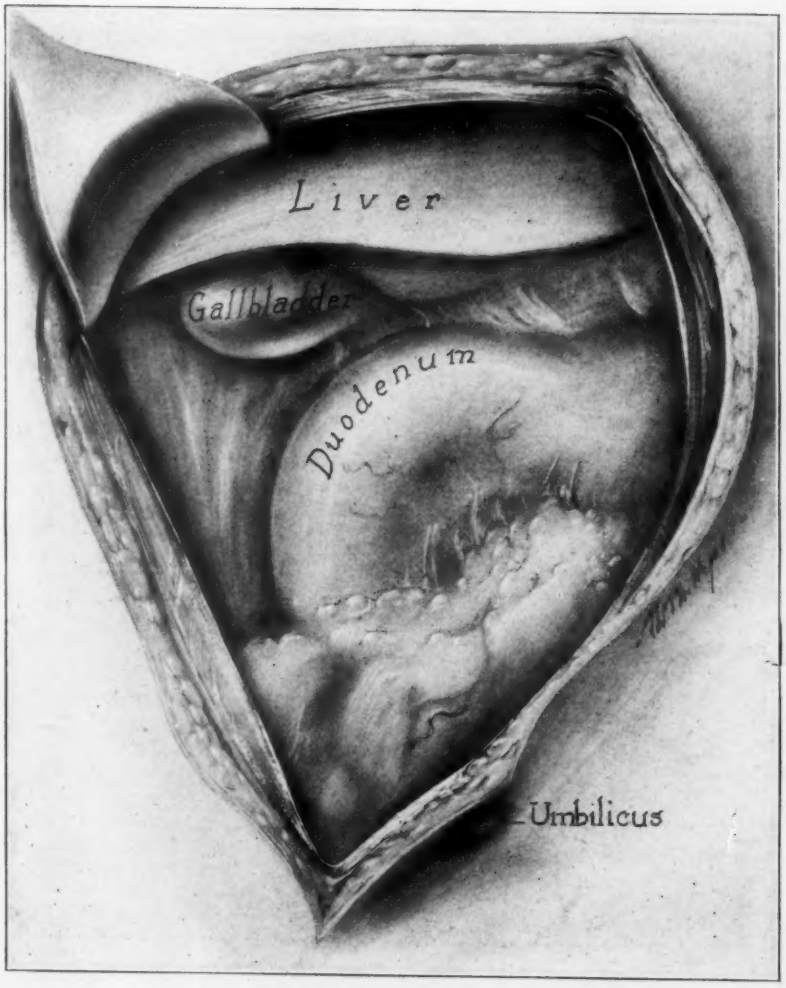

Fig. 6.—Demonstration of the exposure obtained.

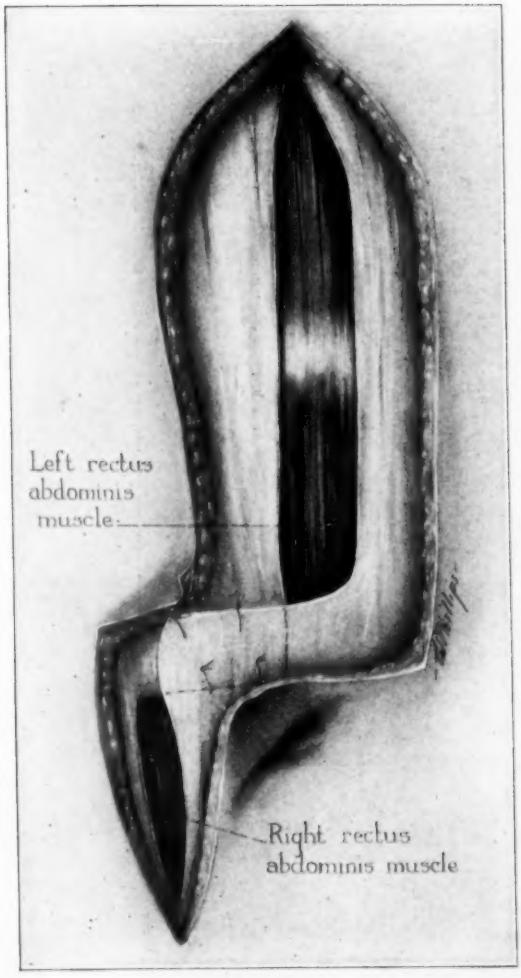

Figure 7

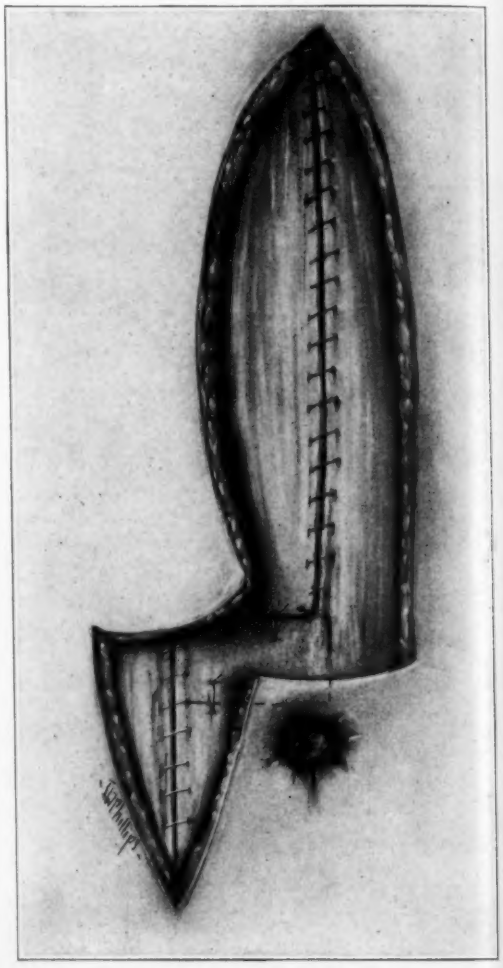

Figure 8

Fig. 7.—First step in the closure. The transverse portion of the incision is imbricated after the manner of the Mayo operation for umbilical hernia. Following the imbrication, the peritoneum is closed with a running suture above and below the transverse incisions.

Fig. 8.—The muscles are allowed to fall back in their accustomed places within the sheath, and the sheath is closed with a running suture of chromic, no. 2.

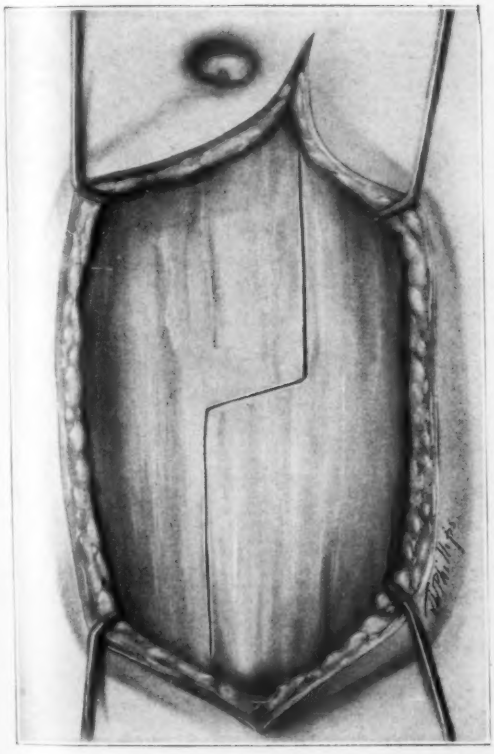

Figure 9

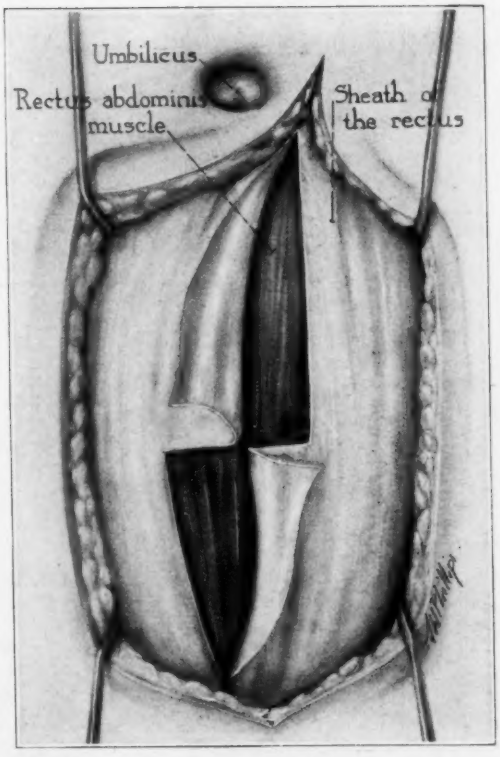

Figure 10

Fig. 9.—The same type of incision is used to prevent hernia in the lower part of the abdomen. One half of the incision is made through the fascia over the left rectus and one-half over the right.

Fig. 10.—The fascia is turned back, showing the right and left rectus muscles exposed.

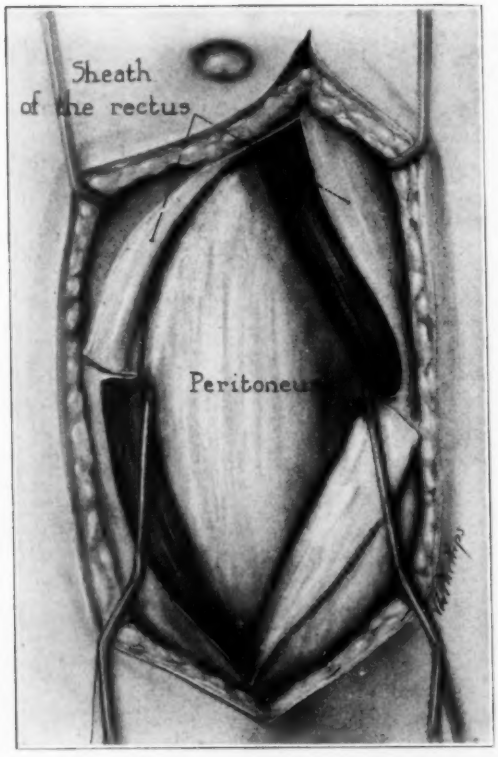

Figure 11

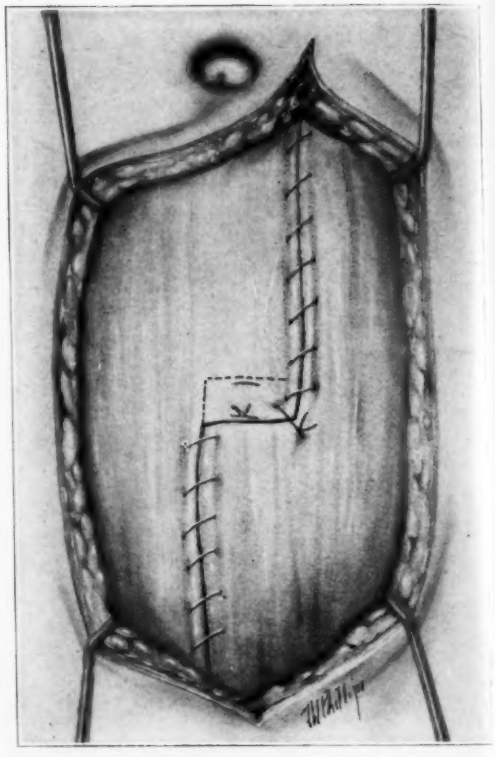

Figure 12

Fig. 11.—The muscle is separated. The left rectus emerges from the sheath above, and the right rectus from the lower sheath.

Fig. 12.—The closure is the same as in the upper abdominal incision. The fascia of the transverse portion of the incision is imbricated from 1 to 2 cm.

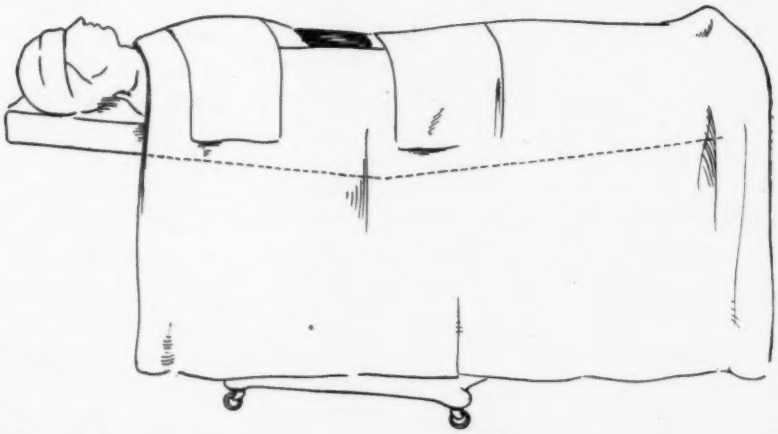

Fig. 13.—When the closure is begun, the patient is flexed on the table, which lessens the tension on the wound.

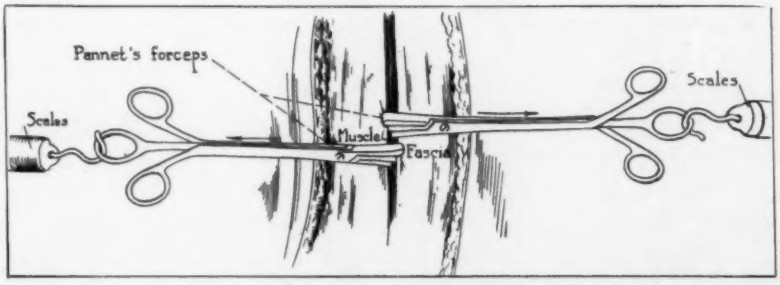

Fig. 14.—The manner in which the lateral tension of the wound can be approximated with forceps and scales.

instead of on one. The strain of abdominal pressure is exerted on the scar in three different places, practically as if there had been three incisions. I have designated the incision as a "three in one incision" because while the abdomen is open it is really one continuous incision, but after closure the effect is that of three distinct suture lines. I believe that this incision lessens the number of postoperative hernias, because after closure the effect is that of three short incisions. As mentioned it has been shown that "the shorter the incision the fewer the hernias." Also, only a few twigs of nerves need be severed and no muscle fibers are cut.

OPERATIVE RELIEF FROM PAIN IN LESIONS OF THE MOUTH, TONGUE AND THROAT*

WALTER E. DANDY, M.D.
BALTIMORE

The recent development of an operative attack on the trigeminal and glossopharyngeal nerves at the brain stem for the cure of trigeminal and glossopharyngeal tic douloureux [1] at once suggested the permanent relief from pain in which the peripheral distribution of both of these nerves are responsible, namely, in chronic ulcers, burns from radium or malignant lesions of the tongue and throat.

The exact form of treatment by which relief from pain is to be sought will necessarily depend on the character, location and rate of growth of the lesion and the general state of the patient's health. At times morphine or other strong sedatives may be the treatment of choice. For the relief from pain confined to the inferior or superior maxillary nerves an injection of alcohol into the peripheral branch may be indicated. Obviously, the operative relief from pain is intended only for a selected group of patients whose general condition and expectancy of life is such as to make it seem advisable.

Since the tongue and pharynx are supplied by two sensory nerves, the glossopharyngeal and the trigeminus, chronic lesions frequently overlap from the domain of one nerve into the other. Under such conditions, the exclusion of only one nerve will have little effect on the intensity of the pain. Both nerves must be divided to give relief.

The trigeminal nerve supplies all of the inner side of the mouth, most of the roof and the floor of the mouth, the anterior two thirds of the tongue and the nasal sinuses. The glossopharyngeal nerve supplies sensation to the posterior third of the tongue, the uvula and the posterior part of the soft palate, the posterior wall of the pharynx and the posterior surface of the epiglottis. Pain is always greatly intensified in ulcerations of the mouth and pharynx because of the passage of liquids and food over the exposed nerve endings. The pain may also be much increased by applications of radium.

The proposal, therefore, for the relief from pain (in selected cases) when the sensory fibers of both nerves are involved or will later probably be involved is the intracranial division of both the fifth and the ninth nerves. Since the intracranial positions of the trigeminal and

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* From the Johns Hopkins Hospital and University.

1. Dandy, W. E.: Section of the Sensory Root of the Trigeminal Nerve at the Pons.—Preliminary Report of the Operative Procedure, Bull. Johns Hopkins Hosp. **36**:2, 1925; Glossopharyngeal Neuralgia (Tic Douloureux), Arch. Surg. **15**:198 (Aug.) 1927.

glossopharyngeal nerves are in such close proximity, precisely the same approach (subcerebellar) has been used in each procedure. It is possible to divide both nerves at the brain stem almost as easily as either. The sensory root of the trigeminal nerve can be severed with much greater ease and with far less time by this new procedure, which has been used exclusively for the past two years at the Johns Hopkins Hospital and University, than by the older approach along the floor of the temporal fossa (Hartley-Krause). After a small unilateral bony defect has been made, only a few minutes are required to divide the sensory root of the fifth nerve either entirely or in part, and only a few additional seconds are needed to resect the glossopharyngeal trunk. Other great advantages of this route for section of the trigeminus are (1) the constant absence of injury of the motor branch of this nerve and (2) the almost complete absence of corneal redness and ulceration—the two principal deterrent features of the Hartley-Krause method. (3) For reasons not yet definitely ascertained, some sensation to the face is usually but not always retained.

REPORT OF A CASE

A sallow, undernourished man, aged 40, was suffering terrific pain in the region of an old ulcer on the right side of the tongue; the pain radiated to the back of the throat, the right ear, the lips and teeth on the right side, the inside of the cheek and the right half of the hard palate. The pain was present almost constantly, and though always severe, the intensity varied from time to time. Exacerbations of the pains always resulted from rubbing the mustache and shaving or lightly rubbing the lower part of the face on the right side. The inside of his mouth burned like fire on the right side. Chewing and swallowing so greatly increased the pain in the mouth and ear that he was afraid to eat or drink. The pain was not relieved by any sedative. It was finally necessary to resort to morphine, and many strong doses were required to bring relief. During the three weeks before operative relief was obtained, it had been necessary to give 130 doses of morphine. The patient became desperate and belligerent until the large amounts of morphine reduced the pain to a point of toleration. Most of the right half of the tongue had been removed several months previously for a chronic ulcer, presumably carcinomatous. A few weeks later, the glands of the neck were removed on the right side. Microscopic sections, however, failed to show carcinoma, either in the ulcer of the tongue or in the glands of the neck. Since the ulcer followed in the wake of a healing Vincent's angina, it is more probable that the original ulcer was benign. Six weeks after the operation on the tongue, radium needles were implanted, and thereafter the pain became violent and unrelenting. On the lateral border of the tongue was a contracture due to the healed lesion. It was covered with epithelium and was not indurated. Actual ulceration was not now visible.

Operation.—Sept. 18, 1927: A unilateral cerebellar exposure was made on the right side. The bony defect extended to the mastoid cells, which, however, were carefully avoided. The cisterna magna was punctured, releasing a large amount of fluid and thereby affording ample room for a subcerebellar exposure. The cerebellum was lifted with a spatula until the cisterna lateralis was brought into view. After evacuation of the fluid of the lateral cistern, one could at once

see the series of cranial nerves on this side. The ninth and the fifth nerves were easily isolated and divided, the former with scissors, the latter with a tiny knife at right angles to a long flexible shaft. The division of both nerves after their exposure probably did not consume more than five minutes, the entire operation taking about forty minutes.

The postoperative course was uneventful. The patient was immediately relieved from all pain, and despite the large doses of morphine which had been given before operation, there has been no further need or desire for the drug. His color, general appearance, weight and behavior rapidly improved. At the time this report was written (Feb. 1, 1928) the patient was back at work and in perfect health. He has gained 30 pounds (30.6 Kg.) in weight, and has been entirely free from all pain since the operation.

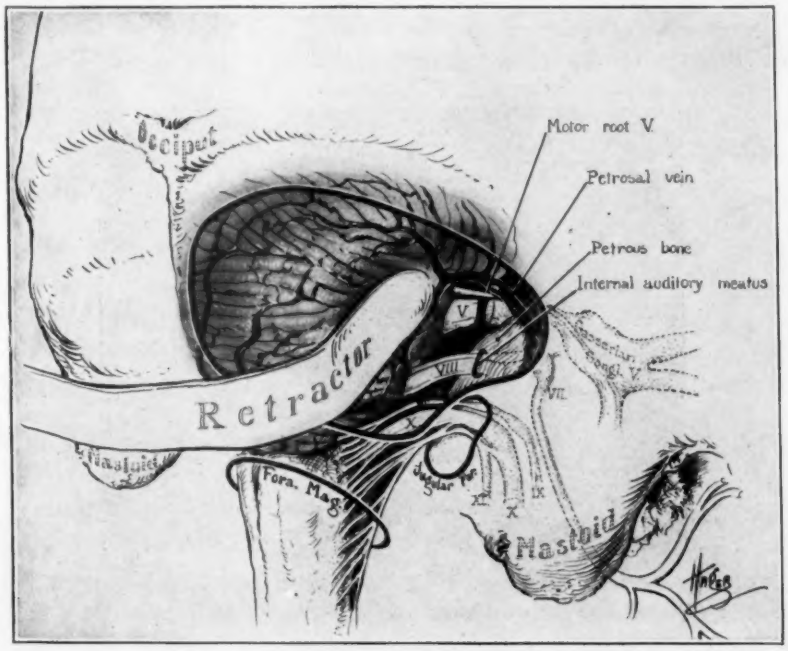

Fig. 1.—Operative approach to the fifth and the ninth nerves at the brain stem.

AFTER-EFFECTS OF OPERATION

The after-effects of the opeartion are confined to the loss of sensation incident to the loss of the two sensory nerves. However, in not one of three patients in whom the glossopharyngeal nerve alone was divided has there been any appreciation of this sensory loss, nor has the loss of taste over the posterior third of the tongue been noticed, although the objective sensory loss was absolute. Loss of sensation over the trigeminal area is only partial as obtained in seven of ten cases after division of the sensory root at the pons. The sensation over the forehead is only a little impaired; that over the second branch is somewhat more affected, and over the third branch, the loss is a little more.

Touch is preserved over all branches, but most acutely over the first branch. Heat and cold can be differentiated over all branches, but most keenly over the first branch. The corneal reflex is retained. This seeming paradox, i. e., preservation of sensation, is the usual story and greatly reduces the subjective feeling of great numbness which obtained after the old operation. It is not due to partial severance of the nerve as might be suspected. Perhaps there are sensory fibers accompanying the motor branch of the nerve which is always preserved intact.

INDICATIONS FOR AND ADVANTAGES OF THE OPERATION

When the sensory domain of the glossopharyngeal nerve is invaded by carcinoma or a chronic or incurable lesion, relief can be obtained only through section of the ninth nerve.[2] Alcoholic injections of the

Fig. 2.—Scar of patient whose fifth and ninth nerves were divided intracranially. The photograph was taken ten days after operation.

nerve are practically precluded because of the intimate relations between the peripheral fibers of the vagus, and also because of the fact that the glossopharyngeal nerve lies in the sheath of the jugular vein and close to the internal carotid artery. Peripheral section of the glossopharyngeal nerve in the neck is much more dangerous than intracranial section of the nerve because of the intimate association with the vagus nerve,

2. T. Fay recently divided the ninth nerve intracranially and the upper three spinal sensory roots by a combined laminectomy and cerebellar exposure. He thought it necessary to divide this group of nerves because the more distant skin areas of the neck had been invaded by an ulcerating carcinoma which was primary in the neck (Intracranial Division of the Glossopharyngeal Nerve Combined with Cervical Rhizotomy for Pain in Inoperable Carcinoma of the Throat, Ann. Surg. **84**:456, 1926.)

injury to which induces profound disturbance of deglutition. The vagus has always been injured when section or avulsion of the glossopharyngeal nerve has been attempted in the neck. Moreover, intracranial section of the central fibers of the ninth nerve makes their regrowth impossible, whereas after peripheral division, the pain would doubtless return. Intracranial section is easier and almost devoid of danger.

Should the domain of the trigeminal nerve alone be involved, and the involvement be only on one side, the relief from pain offers the choice of two methods, (1) injection of alcohol and (2) intracranial section (either partial or total) of the sensory root of the trigeminus. If the lesion is a carcinoma and so rapid in its growth that the duration of life is probably a matter of few months, the injection of alcohol into the inferior or superior maxillary branches of the trigeminus would be preferable.

However, should the probable duration of life be many months or years, or should the lesion be such that the duration of life is not directly affected, division of the trigeminal nerve intracranially by the cerebellar route is far superior to the repeated and painful injections with the added loss of the muscles of mastication.

But when with the same expectancy of life the lesion is such that the sensory domains of both the ninth and the fifth nerves are involved, injections of alcohol will be futile. Intracranial section of the ninth nerve alone will give relief in its distribution; and, as previously noted, when this is done the sensory branch of the fifth nerve is already in view and can be easily divided. It need not be emphasized that when the sensory root of the fifth nerve is divided through the temporal route (Hartley-Krause operation) it is not possible to section the glossopharyngeal nerve at the same time, for it is far afield of this exposure. Moreover, there is far less hesitancy in advising division of the sensory branch of the trigeminal nerve by the cerebellar route than by the temporal approach since trophic disturbances of the eye are eliminated and injury to the motor branch of the trigeminal nerve (muscles of mastication) never occurs; finally, the operation has not been attended with mortality.

There remain the possibilities of relieving pain when the lesion is in the midline of the tongue, mouth or pharynx, and involves the sensory fibers of both trigeminal, or of both ninth, or even perhaps of all four nerves. The cerebellar approach to the intracranial part of these nerves is easily extended to a bilateral exposure by enlarging the unilateral into the bilateral approach which is more or less routine in operations for cerebellar tumors. Whether both glossopharyngeal and both trigeminal nerves could be sacrificed, one can only infer. In a case of bilateral trigeminal neuralgia, the sensory roots of both trigeminal nerves have

been divided by this approach at one sitting and with no added operative difficulties other than the greater time consumed in making a bilateral instead of a unilateral cerebellar exposure. The additional division of both ninth nerves, while not difficult technically, might well be impracticable because of the loss of the gag reflex.

Whether chronic lesions of the tongue or nasopharynx would ever present the need of such operative relief, I am not prepared to say. In such cases, bilateral alcoholic injections of the inferior maxillary nerve would be precluded because both motor branches of the trigeminus would be paralyzed and swallowing made impossible. Relief from such pain could hardly be obtained safely except by section of the sensory roots at the pons where the motor roots are safely removed.

Whether both glossopharyngeal nerves could be divided for the relief from pain cannot be answered by precedent. Though technically easy and safe, the absence of the gag reflex on both sides would probably make it impractical. Division of either the ninth or the fifth nerve, or of both on one side, may also be of advantage in permitting the application of radium to a malignant lesion without pain, immediately or subsequently.

SUMMARY AND CONCLUSIONS

An operation is presented for the complete and permanent relief from pain associated with chronic, benign and malignant lesions of the mouth, nose, tongue and throat. When the pain is referable to the sensory domain of both the glossopharyngeal and trigeminal nerves on one side, there is no other way of permanent relief. Under such conditions the glossopharyngeal nerve and the sensory root of the trigeminus can be divided at the brain stem (subcerebellar approach), both nerves being exposed simultaneously in the same operative field. Both nerves can be divided easily, quickly and with little danger to life or function.

NOTE: Since this article was sent for publication, three additional cases of combined fifth and ninth nerve divisions have been performed. In two of the patients the upper three cervical sensory roots have also been divided intradurally because the malignant lesions had extended into the domain of the cervical nerves.

BRONCHOBILIARY FISTULA *

M. G. SEELIG, M.D.
AND
J. J. SINGER, M.D.
ST. LOUIS

During September, 1927, we saw a patient in whom a bronchobiliary fistula developed. The infrequency of this type of lesion prompted us to collect and analyze the literature on bronchobiliary fistulas. We had just instituted our studies when the admirable article by Morton and Phillips [1] appeared, making it not only unnecessary but even unwise to publish another detailed report. In the paper by Morton and Phillips will be found everything pertaining to the history, etiology, pathologic characteristics, symptomatology, prognosis and treatment of bronchobiliary fistula. However, it may be worth while, in a condition so unusual, to submit a report of the case of our patient merely as a matter of record.

REPORT OF A CASE

L. R., an obese, white, married multipara, aged 39, was operated on for appendicitis by one of our colleagues in St. Louis, in the hope of relieving headache, constipation, nausea and pain in the lower right quadrant. The appendix was found to be inoffensive, and exploration of the abdomen yielded no positive information. She was discharged on Sept. 27, 1921, feeling very well. Six weeks later, pain developed in the upper right quadrant, radiating to the back, and was accompanied by nausea and vomiting; the pain occurred in attacks, but was unaccompanied by jaundice or febrile symptoms. Her surgeon decided that the symptoms warranted a direct exposure of the gallbladder. The gallbladder, containing three stones, was small, and bound down to the liver and the duodenum so firmly that it was removed with much technical difficulty. The cystic duct was clamped, and the clamp was left in situ for several days. Six days after the operation, a biliary fistula established itself, and when the patient was discharged from the hospital, eight weeks after operation (April 12, 1924), there was a free discharge of bile from an abdominal fistula in the operative scar.

Six months later, the patient was readmitted to the hospital, complaining of prostration, nausea without vomiting, universal pruritus and persistent diarrhea. She was deeply jaundiced, the stools were clay-colored, showing no trace of bile, and the biliary fistula discharged profusely. At that time, pain was a negligible factor. Her surgeon, suspecting that he had overlooked a stone of the common duct, attempted to locate and remove it; however, owing to dense adhesions and the poor physical condition of the patient, he was unable to locate the duct. After this operation, the patient was seen by Dr. Evarts Graham, who expressed the opinion that there was an obstruction of the common duct, the nature of which

* Submitted for publication, Feb. 2, 1929.

* From the Chest and Surgical Services of the Jewish Hospital, St. Louis.

1. Morton, J. J., and Phillips, E. W.: Bronchobiliary Fistula, Arch. Surg. **16**:697 (March) 1928.

was not entirely clear, but which was probably the result of an injury to the duct at the time of the former operation, with resultant stricture, and that another surgical attempt should be made to relieve her.

We concurred fully in the opinion of Graham, and on Nov. 25, 1925, an operation was performed. This operation, which was technically difficult owing to the obliteration of all landmarks due to dense adhesion and the absence of the gallbladder, disclosed that the lower portion of the common duct was missing. Between the stump of the duct and the duodenum there was a gap of 1½ inches (3.77 cm.). The duodenum was mobilized, and a small catheter was fixed in the end of the common duct which led into the lumen of the duodenum through a puncture of its superior wall; the duodenum and common duct were then approximated so that they just touched. Sutures held these two structures in loose apposition, and omentum was wrapped around the site of the anastomosis. Following the operation, the stools became colored, the discharge of bile through the fistula ceased, the jaundice cleared up and the patient rapidly returned to a normal condition. The catheter was passed by rectum on the twenty-fourth postoperative day, and the patient left the hospital in excellent condition a month after the operation.

Ten months later, on Sept. 24, 1927, the patient was readmitted to the hospital. She said that she had not felt normal since the last operation; however, she was able to do her work and was not compromised by any definite symptoms pointing to the biliary tract until eight months after operation, at which time she had an attack of nausea and vomiting which lasted three days. Jaundice was not present, though she was almost constantly plagued by pruritus. She did not consult a physician, in spite of the fact that the attacks of nausea and vomiting were repeated at frequent intervals. Finally, after a month of the illness and three days before admission to the hospital, she had a violent attack of pain in the right upper quadrant.

Symptoms and signs at that time were as follows: deep jaundice, yellow sclerae; pale gray stools; highly colored (bile) urine; constant and severe general pruritus with dermatitis from scratching (till blood flowed); acute pain in the region of the liver referred to the back and right shoulder; nausea and vomiting; a temperature of 102 or 103 F., and chills. Physical examination disclosed evidence of compression of the lower lobe of the right lung. Fluoroscopy and roentgenograms showed a high fixed diaphragm on the right side, a normal upper lobe of the right lung with a compensatory air content in the left lung. The white blood count ranged from 13,000 to 22,000.

The history and the previous operations, symptoms and physical signs all pointed to an obstruction of the bile passages complicated by subphrenic abscess or pneumonia of the lower lobe of the right lung. An exploratory operation was decided on, but the condition of the patient was grave, and it was decided to wait a few days. On September 27, definite bronchial breathing with increasing dulness in the lower lobe of the right lung indicated pneumonia. Under these circumstances, operation was postponed. When a roentgen examination was made at that time, we found evidence of a dense shadow in the lower lobe of the right lung extending up to the fourth rib anteriorly. A diagnostic pleural puncture was made, but no fluid was found.

The usual expectant treatment for pneumonia was instituted. On September 30, the patient coughed up lemon-colored sputum which had a bitter taste. The Gmelin test showed the presence of bile. For the next few days, the patient raised considerable purulent sputum heavily stained with bile. The jaundice cleared rapidly with the discharge of the bile through the bronchobiliary fistula.

On Oct. 5, 1927, an attempt was made to outline the bronchobiliary fistula by the introduction of iodized oil into the bronchial tree. Unfortunately, we were unsuccessful in this procedure. The patient improved gradually, and the signs of the pneumonic condition of the lobe of the right lung diminished. The patient was discharged from the hospital on October 22, much improved. At the time of writing, one year later, she showed recurrent attacks of jaundice, but neither pain nor cough.

COMMENT

Bronchobiliary fistula is unusual, and in this case was not considered a possibility until bile appeared in the sputum. At the time of the illness (Sept. 9, 1927), it was thought that the fever, chills and signs of septic pneumonia were secondary to a subphrenic accumulation of bile and pus. One occasionally sees bile leakage accumulate either in the subphrenic space or in a dead space about the cystic duct. This fluid frequently gives rise to considerable pain and to jaundice until the pocket is opened. It is most probable that the dilatation of intrahepatic biliary passages occurred, with secondary inflammation, leading to abscess formation and perforation into the subphrenic space. Later, the subphrenic abscess perforated the diaphragm, establishing a bimucous fistula between the bronchial tree and the intrahepatic bile capillaries and ducts through the intermediate agency of a suppurative pneumonitis. Prompt relief from symptoms followed the expulsion of bile and pus through the bronchial tree. It would have been instructive to have obtained a picture of the two connecting cavities of lung and liver with iodized oil, but the attempt to introduce the oil through the lung was unsuccessful. A study of the literature shows that this procedure was attempted by Oltiker,[2] with negative results. A study of the roentgenograms showed clearly the pulmonary lesion at the time of the acute symptoms and the clearing up of the pneumonic shadow after the bile was expelled.

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2. Oltiker, quoted by Morton and Phillips (footnote 1, page 737).

ENDOMETRIOMA OF THE TERMINAL ILEUM, APPENDIX AND CECUM *

F. N. G. STARR, C.B.E., M.B.
TORONTO

Since Sampson's [1] exhaustive article on perforative hemorrhagic (chocolate) cysts of the ovary, one finds from time to time many and varied evidences of endometriosis. I have seen several such cases [2] in which the appearance of the uterus closely resembles a leiomyoma, but in which there are many firm dense adhesions to the ovaries, pelvic wall, rectum and sigmoid. In these cases, when trying to arrive at a definite diagnosis, there has always been one definite symptom of which all the patients have complained, pain in the rectum preceding and often accompanying defecation.

The case I shall describe is, I think, unique in that there has never been any menstrual disturbance, and the patient has always been considered a strong, healthy member of her sex.

REPORT OF A CASE

Dr. Donald MacGillivray asked me to see a maiden lady, aged 38, on the evening of March 16, 1927. The history was that for several days she had experienced some discomfort in the right side of the abdomen, which had become more pronounced during the previous night. There had been some constipation, and associated with this there was some nausea but no vomiting. On examination tenderness was found in the right iliac fossa, a comparative rigidity only, but at times a mass could be felt. When this was palpated, a peristaltic wave was observed to extend to the mass. There was evidence of free fluid in the peritoneal cavity. I took this to mean a slowly leaking appendicitis, around which omentum had become lapped, and as the inflammatory reaction increased a partial obstruction had developed. The leukocyte count was 14,000.

When the abdomen was opened, a considerable amount of turbid serum was evacuated. When the cecum was brought into the wound, accompanied by the terminal ileum, no appendix could be seen, nor was there any omentum around the mass. A careful inspection was made to ascertain if the appendix was buried in the posterior wall of the cecum, but none could be found. Because of the almost complete obstruction, a resection was decided on. The terminal ileum about 6 inches (15.24 cm.) from the ileocecal valve, the cecum and part of the ascending colon were removed, and an end-to-end anastomosis was done over the rubber tube.[3] The convalescence was uneventful, the tube being passed per rectum on the seventh day. The patient has continued in perfect health.

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* Submitted for publication, Feb. 11, 1929.

1. Sampson, J. A.: Perforating Hemorrhagic (Chocolate) Cysts of the Ovary: Their Importance and Especially Their Relation to Pelvic Adenomas of the Endometrial Type, Arch. Surg. **3**:245 (Sept.) 1921.
2. Shirer, J. W.: Canad. M. A. J. **18**:151 (Feb.) 1928.
3. Starr, F. N. G.: Tr. Am. Surg. Soc. **40**:260, 1922.

The pathologist, Dr. W. L. Robinson, reported as follows: The gross specimen consisted of a portion of bowel, measuring 15.5 cm. in length. Its lumen was narrowed by a thickening which involved about two thirds of the circumference of the bowel for a distance of about 2.5 cm. at its longitudinal axis. On one side of the constriction, the wall of the bowel showed a greater circumference than that on the other side. The thickening caused a partial obstruction of the bowel. The lumen barely admitted the finger tip. The cut surface of the bowel was an opaque creamy white and was fibrous. Its margin was indistinct. On microscopic examination, the thickened wall of the bowel was seen. The muscle fibers were hypertrophied, and the fibrous connective tissue of the subserosa was increased in amount. The subserous and the muscle coat, almost up to the mucosa, were invaded by glands typical of endometrium along with stroma precisely like that of endometrium. Some of the glands were large and contained red blood cells and epithelial cells with hemosiderin. There was no inflammatory infiltration and no evidence of malignancy. The appendix as such was not recognized, probably being drawn up into the fibrous tumor mass.

The diagnosis was endometriosis.

The extraordinary feature of this case is that apparently the uterus and adnexa were normal and there was no sign of a chocolate cyst of the ovary. The inference, of course, is that at some time the appendix had been in contact with the fimbria and thus some endometrial cells had come in contact. Possibly it may have become adherent and as the obstruction increased and peristalsis became more vigorous, it was detached, although there was no sign of a recent adhesion on the part removed; however, her first discomfort a few days previously may have been caused in this way.

THIRTY-EIGHTH REPORT OF PROGRESS IN ORTHOPEDIC SURGERY

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ARTHUR VAN DESSEL, M.D.

LOUVAIN, BELGIUM

(Concluded from page 2416)

MISCELLANEOUS

The Adult Cripple.—O'Reilly,[49] in his chairman's address before the Section on Orthopedic Surgery of the American Medical Association, selected for his theme the problem of the adult cripple, and pointed out the all important rôle of orthopedic surgery in helping him to attain economic independence. He urged all orthopedic surgeons to bend their efforts toward improving the standards of treatment and providing better and increased institutional facilities. In order to secure the greatest degree of vocational rehabilitation, it was necessary to obtain the maximum physical rehabilitation. Not only humanitarian motives but economic principles justified the establishment of adequate hospitals manned by expert staffs devoted to the treatment of the adult cripple.

[ED. NOTE.—We believe that O'Reilly has called attention to one of the greatest needs in caring for the sick. Adequate provision in the way of hospital care has been made for the acutely ill patient, and a good beginning has also been made in providing facilities for the treatment of crippled children. The problem that is as yet almost untouched is that of the adult patient with chronic disease. With proper institutional facilities, the wage earning ability of many of these could be restored,

49. O'Reilly, Archer: Adult Cripple, J. A. M. A. **91**:137 (July 21) 1928.

and this would relieve society not only of the burden of their care, but of that of providing for those dependent on them.]

Osteochondritis Dissecans.—Reporting on a study of patients with osteochondritis dissecans, Geyman [50] pointed out that the condition was found chiefly in young adults, and that the sites most commonly involved were the medial condyle of the femur and the external condyle of the humerus. Of the various theories that have been put forward to explain the origin of the disease, he thought that trauma was the most likely cause.

Wolbach and Allison [51] obtained the entire knee joint of a patient who had osteochondritis dissecans, and were able to make a thorough study not only of the loose fragment, but of the bed from which the fragment came and also of the underlying bone. They found that the fragment had been produced by a fracture into a cystlike cavity that had developed in the underlying bone. That the cystic degeneration found in this specimen accounted for all cases of osteochondritis dissecans was not claimed, but it probably offered an explanation of certain cases.

Damage to Bone Growth Resulting from Exposure to Roentgen Rays.—Beck [52] made a report of six patients in whom a marked limitation of bone growth was noted after repeated exposure to roentgen rays for the treatment of tuberculosis. The treatment had been given from five to fourteen years previously at a time when roentgen treatment was employed in heavy doses. In one patient, the shortening amounted to 15 cm. The writer was inclined to the view that all of the cells of the epiphyseal region rather than only cells of specialized function were damaged. He based this opinion on the general changes noted in the roentgenograms.

[Ed. Note.—Beck's observations are important, if correct, but one would wish to be certain that the shortening resulted from the roentgen treatment rather than from the disease process itself.]

Osteomyelitis Due to Monilia.—Connor [53] described a case of osteomyelitis which was apparently caused by infection with *Monilia* (a type of yeast organism). The patient was a girl, aged 19, who entered the hospital with several draining sinuses located above the elbow. Later, an abscess developed over the buttock, and was found to connect with a focus of osteomyelitis in the ilium. There was no fever and no leukocytosis. An organism was recovered from the pus which was identified as *Monilia psylosis.*

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50. Geyman, M. J.: Radiology **11**:315 (Oct.) 1928.

51. Wolbach, S. Burt; and Allison, Nathaniel: Osteochondritis Dissecans, Arch. Surg. **16**:1176 (June) 1928.

52. Beck: Zentralbl. f. Chir. **55**:2849, 1928.

53. Connor, C. L.: J. Infect. Dis. **43**:108 (Aug.) 1928.

The Functional Importance of Equalization of the Length of the Legs.—That equalization of the length of the legs when one leg was shorter than the other was of great importance for the functional development of the shorter leg, especially in cases of paralysis and other conditions, was stated by Deutschlaender.[54] The shorter leg was always weaker and more easily fatigued, and rendered the gait uncertain. Raising the sole of the shoe was never a satisfactory means of solution, because it never increased the locomotor power, although it did improve the equilibrium. The writer preferred to shorten the longer leg; sometimes it was necessary to shorten it in more than one place. He had performed the operation of shortening the bone in seventy patients, and had been entirely satisfied with the results. The operation had resulted in making the legs of almost equal length and in greatly improving the gait. All of the patients were enabled to wear ordinary shoes.

[ED. NOTE.—The question to determine here is whether it is better policy to equalize the length of the legs by shortening the long, or normal leg, or by lengthening the short leg. Until recently, the results of the procedure of lengthening the bone were uncertain, but substantial progress has been made by Abbot in the use of an improved method described in a previous "Report of Progress in Orthopedic Surgery." [55] As familiarity with this technic is acquired, we believe that it will be preferred to the operation of shortening the bone.]

Spontaneous Dislocation and Destruction of the Tendon of the Biceps Brachii.—From studies of the shoulder joint in cadavers, Meyer [56] concluded that spontaneous partial or complete forward dislocation of the portion of the biceps tendon lying between the tuberosities of the humerus was not an uncommon occurrence. It probably occurred most frequently in laborers past middle age. Division of the tendon in this portion might occur as the result of degenerative changes and of the process of wear and tear, but usually the tendon reattached itself to the humeral shaft just beyond the lesser tuberosity. If this reattachment did not occur, a marked atrophy of the lateral belly of the biceps muscle resulted.

Traumatic Osteoporosis of the Carpal Bones.—Buchman [57] discussed osteoporosis of the carpal bones (Kienböck's disease; Preiser's disease) in respect to etiology, pathology and treatment. He believed with Lériche that in this disease there was a disturbance of vasomotor

54. Deutschlaender, K.: Ztschr. f. Orthop. Chir. **51**:64, 1929.

55. Abbott, LeRoy: Reference in Thirty-Fourth Report of Progress in Orthopedic Surgery, Arch. Surg. **16**:620 (Feb.) 1928.

56. Meyer, A. W.: Spontaneous Dislocation and Destruction of Tendon of Long Head of Biceps Brachii, Arch. Surg. **17**:493 (Sept.) 1928.

57. Buchman, Joseph: Ann. Surg. **87**:892 (June) 1928.

equilibrium; that a fracture frequently accompanied, but was not essential to, the process; that absorption began regardless of whether a fracture was present or not, and that fracture and extensive destruction occurred as a result of the atrophy. Conservative treatment in the form of immobilization in the "cock up" position should be tried for a reasonable length of time, but if disability persists, then the involved bones should be excised. In the hands of the author, the operative treatment had given good resuls.

He reported seven cases; in three, the process involved only the scaphoid; in the fourth the scaphoid and semilunar; in the fifth the scaphoid, semilunar and os magnum; in the sixth the semilunar, os magnum, and unciform, while in the seventh the os magnum and unciform were affected.

[ED. NOTE.—Traumatic osteoporosis is a most baffling condition and sometimes defies all treatment. Its cause is obscure, but the general tendency is to regard it as a trophoneurosis. All surgeons who have had first hand acquaintance with the lesion will welcome any new light that may be shed on it.]

Stenosing Fibrous Tendovaginitis Over the Radial Styloid.—Since de Quervain's original description of stenosing fibrous tendovaginitis over the radial styloid, Schneider [58] found that 144 cases illustrating the condition had been reported. It was caused by excessively monotonous motions of the thumb in abduction and extension, these leading to a thickening of the tendon sheaths of the abductor pollicis longus and the extensor pollicis brevis as they passed over the radial styloid. It occurred more often in women.

In most of the patients relief was to be obtained by complete immobilization with the thumb in a position of abduction and extension over a period of from six to eight weeks. In a few obstinate cases, it was necessary to expose the seat of the trouble by an incision and to split the tendon sheath.

SURGICAL PROCEDURES ON THE BONES, JOINTS AND TENDONS

Spinal Fusion with Osteoperiosteal Graft.—Allison [59] described the technic of spinal fusion with the aid of the osteoperiosteal graft which had been employed at the Massachusetts General Hospital for a number of years. The operation consisted essentially of the Hibbs procedure with the addition of a thin osteoperiosteal graft in the shape of a long flexible ribbon which was removed from the anteromedial surface of the tibia and laid down on the surface of bone chips and fragments pro-

58. Schneider, Chester C.: Surg. Gynec. Obst. **46**:846 (June) 1928.

59. Allison, Nathaniel: Surg. Gynec. Obst. **46**:826 (June) 1928.

duced by the spinal operation. In the author's opinion, the addition of this osteogenetic material served to stimulate the production of a greater amount of new bone than would otherwise be obtained and hence represented an additional guarantee of a successful outcome. The graft was always removed by a second operating team and hence did not prolong the time of the operation or add to the shock.

Enlargement of Parturient Canal by Bone Graft.—Albee [60] reported that in two patients with contracted pelves he had successfully enlarged the pelvic outlet to permit childbirth. The technic consisted of inserting at the symphysis pubis a bone graft 1½ inches (3.7 cm.) long which was removed from the tibia.

[ED. NOTE.—While concerning chiefly the sister specialty of obstetrics, this procedure ought to be of much interest to orthopedic surgeons, particularly as it affects the mechanics and function of the sacro-iliac joints.]

Transtrochanteric Approach to the External Iliac Fossa in Osteoplastic Operations.—For certain operations on the hip, such as the shelf operation in congenital dislocations, the procedure of arthrodesis and bone grafting in ununited fractures, Calvé [61] described a new T-shaped incision. The long vertical limb of the incision was made to extend from the base of the lateral surface of the greater trochanter to the iliac crest at the junction of the anterior third with the posterior two-thirds. From the summit of this incision two shorter cross incisions were made, one extending anteriorly and the other posteriorly following the curve of the iliac crest. The deeper tissues were then separated, exposing the greater trochanter but without dividing the muscles attached to the latter. The edges of the gluteus medius and gluteus minimus were then defined and separated. Proceeding carefully at this point, the operator exposed the arterial and venous branches of the gluteal vessels; these branches were then clamped and cut between ligatures. The greater trochanter was next sectioned by a vertical incision extending from its summit for a distance of from 1 to 2 cm., at which point it separated into two oblique incisions, the anterior one running forward and outward, the posterior one running backward and inward. The two fragments of the trochanter were then retracted without being completely separated from their femoral attachments. One thus obtained a wide exposure of the capsule of the joint, the acetabular margin and the external surface of the ilium.

[ED. NOTE: It is difficult to see how injury to the nerve supply of the tensor fasciae femoris muscle could be avoided by this incision.]

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60. Albee, F. H.: Surg. Gynec. Obst. **46**:845 (June) 1928.

61. Calvé, Jacques: Presse méd. **36**:695 (June 2) 1928.

Arthroplasty of the Knee.—Campbell [62] discussed the results of arthroplasty of the knee, basing his remarks on a study of 111 patients. He employed an operation which remodeled the lower end of the femur in the form of a single condyle extending across the transverse diameter of the bone, this articulating with a concavity in the upper surface of the tibia. Fascia was interposed between the ends of the bones. In forty-three of 111 patients whom he was able to follow, a useful range of motion resulted, varying in extent from 35 to 120 degrees. As experience with the operation increased, a betterment of the functional results was noted. The indications, contraindications and postoperative treatment were thoroughly discussed.

Albee [63] described how his own conservative attitude of ten years ago concerning arthroplasty for bony ankylosis of the knee had changed to one of moderate enthusiasm because of ten successful results he had obtained by operation since 1920. He analyzed these cases, calling attention to the technical features which had contributed to the favorable outcome. He believed that the technic of wedge-shaped arthroplasty with the reconstructed convex femur fitting into the concave tibia maintained mobility and at the same time prevented lateral instability. For interposition, he employed fascia which was covered with a layer of fat. He did not believe that old healed tuberculosis of the knee was necessarily a contraindication to arthroplasty.

[ED. NOTE.—The increasing number of favorable reports on arthroplasty of the knee shows that in skilled hands the operation here yields better results than in the case of most of the other joints, with the exception of the elbow and the jaw.]

The Operation of Stripping the Os Calcis.—Describing the technic of his operation of stripping the os calcis for pes cavus, Steindler [64] stated that he always used the medial incision and never the incision around the heel. He emphasized the importance of thoroughly stripping the structures as far forward as the calcaneocuboid joint. In addition to the stripping of the os calcis, wrenching of the foot or some other operation on the bones often was necessary to restore and maintain the balance of the foot. An analysis of the results obtained in 201 patients who had been followed for a number of years was presented.

A Conservative Operation for Bunions.—McBride [65] described an operation for the correction of hallux valgus which he had employed in a large number of cases. The operation consisted of transplanting the conjoined tendons of the adductor muscle group of the great toe to

62. Campbell, Willis C.: Surg. Gynec. Obst. **47**:89 (July) 1928.

63. Albee, F. H.: Surg. Gynec. Obst. **47**:312 (Sept.) 1928.

64. Steindler, Arthur: Surg. Gynec. Obst. **47**:523 (Oct.) 1928.

65. McBride, Earl: J. Bone & Joint Surg. **10**:735 (Oct.) 1928.

the dorsum of the head of the first metatarsal bone. The bursa was also dissected out and the bony prominence chiseled away. After the capsule was repaired and the wound closed, a light plaster casing was applied. McBride permitted weight bearing at the end of two weeks.

FRACTURES

Fractures in Industry.—From an analysis of the experience with several thousand fractures covering a period of twelve years, Davis [66] found that it was possible in simple uncomplicated fracture to predict the cost of treatment in the average case fairly accurately. The average period of time lost in this group of cases was 27.3 days. The actual cost to the injured employee was based on the average time lost and the average of the different earnings, and amounted to $6.00. The actual cost to the employer was $20.97 a week when the patient was not hospitalized and included the cost of taking care of the fracture plus compensation. When the patients were hospitalized, their sustenance had to be added, and this amounted to $31.78 a week. When the patients were sent to a private hospital, the cost was much greater and included the minimal ward rate of $3.50 a day, the laboratory fee and the cost of materials, the professional charge of the physician and compensation to the employee. The figures indicated that the percentage of disability could be reduced by skilful operative procedures and careful postoperative treatment. In many instances the period of disability was prolonged, and the cost both to himself and to his employer was increased by the poor physical condition of the patient.

Bone Repair and the Healing of Fractures.—Cowan [67] produced simple fractures in the bones of kittens and studied the reparative processes grossly, microscopically and roentgenologically at intervals varying from twelve hours to thirty-four days. He concluded that the periosteum was more essential in healing than the medullary tissue or cortical bone. Fibrous union or pseudarthrosis was more apt to develop following extensive destruction of periosteum at the fracture line or after wide separation of the fragments. If after fibrous union was established, weight bearing was permitted, a false joint often developed at the fracture site. To overcome this, it was necessary to excise the fibrous and cartilaginous tissue.

Mock [68] was of the same opinion as Cowan and cited clinical and experimental evidence to substantiate his claim that of all the elements of bone, the periosteum was the most important in bone repair. In delayed union or loss of bone substance, he would practically always use

66. Davis, P. A.: Fractures in Industry, J. A. M. A. **91**:695 (Sept. 8) 1928.
67. Cowan, John: Ann. Surg. **88**:749 (Oct.) 1928.
68. Mock, H. E.: Surg. Gynec. Obst. **46**:641 (May) 1928.

the periosteal graft or if the defect were too great he would prefer an osteoperiosteal strip.

In experiments on kittens, Glaessner and Hass [69] found that thymectomy delayed the formation of callus, and that injection of an extract of thymus hastened bone consolidation. In a series of experiments on older cats, the influence of extracts of various endocrine glands was tested. Thymus extract was found to be the most potent in its effect on formation of callus. The next most potent extract was that of the parathyroids. These authors had employed the extract in a considerable number of patients with delayed callus formation and had noted beneficial results.

Fine and Brown [70] performed some experiments on dogs to study bone repair under the influence of parathyroid extract-Collip. They concluded that the experiments, although small in number, showed that the parathyroid extract delayed the speed of deposition of calcium in regenerating bone in young dogs, whereas in adult dogs no clear evidence as to its potency in this or in the reverse direction was obtained. In their opinion the practical significance of these observations was that the clinical use of the parathyroid extract for delayed bone union was not based on any sound principle, could do little if any good and, in fact, might do harm.

Robinson [71] made a study of the rôle of the circulation in the healing of fractures and came to the conclusion that an inadequate blood supply was one of the most important factors contributing to delay and failure of bone repair. He emphasized the necessity of an adequate supply of new blood vessels for the deposition of lime salts in the callus. He pointed out the importance of making provision for expansion of the surrounding soft structures in the treatment for fractures, of avoiding compression by tight bandages, and of splitting circular plaster casing on two sides.

Fracture and Dislocation of the Sternum.—Three instances of fracture or dislocation of the sternum were reported by Holderman.[72] From a statistical review, he found that this type of fracture represented considerably less than 1 per cent of all fractures. It was usually produced by a direct blow, but might also result from indirect violence. The commonest site of separation of fragments was at the junction of the manubrium and gladiolus. In most instances the dislocation could be satisfactorily reduced by closed methods, but open operation was often justified.

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69. Glaessner, K., and Hass, I.: Klin. Wchnschr. **7**:1633 (Aug. 26) 1928.

70. Fine, Jacob; and Brown, Samuel: New England J. Med. **198**:932 (June 21) 1928.

71. Robinson, Wilton H.: Rôle in Healing of Fractures, Arch. Surg. **17**:420 (Sept.) 1928.

72. Holderman, Herbert: Ann. Surg. **88**:252 (Aug.) 1928.

Fracture of the Clavicle.—Funston [73] described a splint for the treatment of fractures of the clavicle. It was based on the principles of the clavicular cross, but did away with the mechanical objections to it of bulkiness and of pressure against the vessels and nerves in the axilla as well as the loss of tension when the dressings had loosened. The splint was made of steel rods about ¼ inch in diameter and was furnished with special pressure drums covered with felt which exerted a strong pressure on the front of the heads of the humeri in a backward direction. Steel rods passed backward from these, arching under the axillae without making any pressure and terminated in two pressure pads pressing against the back in the interscapular region. These were connected with a vertical member of the brace which extended down the back for the purpose of exerting leverage, its end being held in place by a circular strap about the pelvis.

Yates and Guest [74] recorded an unusual complication of fracture of the clavicle. A woman, aged 41, died of cerebral embolism due to thrombosis of the subclavian artery which had been caused by pressure of an ununited fracture of the clavicle.

[Ed. Note.—Funston's splint is ingenious and ought to be effective. Unfortunately, the services of an experienced brace fitter and a considerable amount of time are required for its manufacture.]

Vertebral Fractures.—Wilmoth [75] presented the case histories of seventeen patients who had fractures of the transverse processes or chip fractures of the lumbar vertebrae. He was of the opinion that such injuries were of relatively frequent occurrence and were due to forcible hyperextension of the spine or to sudden muscular action. The trauma was usually slight, and this led to incorrect diagnosis as the injury did not seem sufficient to justify roentgen examination. As far as treatment was concerned, it ought to be the same in chip fractures as in other types of fracture, namely, rest and immobilization.

[Ed. Note.—The chief feature of interest in this article is the suggestion that hyperextension of the spine may cause a chip fracture of the spine as well as hyperflexion. The observation needs to be confirmed.]

Kümmell's Disease.—In a thorough article reviewing the literature and what is known of the pathology, Cardis, Walker and Oliver [76] reported fourteen cases of Kümmell's disease. They were able to study the lesion in a patient who died from an intercurrent disease. Examina-

73. Funston, Robert: J. A. M. A. **91**:794 (Sept. 15) 1928.

74. Yates, A. Gurney; and Guest, Denton: Lancet **2**:225 (Aug. 4) 1928.

75. Wilmoth, Clifford L.: Fractures of Lumbar Vertebra Due to Hyperextension and Extreme Muscular Action, J. A. M. A. **91**:6 (July 7) 1928.

76. Cardis, J.; Walker, G. F., and Oliver, R. H.: Brit. J. Surg. **15**:616 (April) 1928.

tion of the specimen showed no signs of injury of the spinal cord, no evidence of tuberculosis or abscess, no bone necrosis and the absence of pathologic changes in the intervertebral disk. The second lumbar vertebra was wedge-shaped. The margins of the bone were intact, except for a small fracture in the upper anterior part. The spongiosa showed multiple small hemorrhages. On microscopic examination the bony framework showed marked atrophy with a changed appearance of the marrow, the cells of which were decreased in number and stained poorly.

Fractures of the Pelvis.—Sever [77] made a study of fifty-one patients with fractures of the pelvis. He classified these as follows: fractures of the ilium, twelve; fractures of the pubic arch, twenty-five, and fractures involving the acetabulum, fourteen. In fractures of the ilium without lesions of the abdominal contents, treatment gave good results. Acetabular fractures were of two types: first, those which merely showed fissures in the acetabulum as well as those with slightly greater involvement, that is, where there had been a little protrusion of the inner wall or a spicule broken off from the inner table; second, those which showed protrusion of the whole acetabular wall or even a penetration of the femur into the pelvis.

In the first class, good function and little or no disability resulted. In the second class there was always some disability, often considerable, with some limitation of the motions of the hip. Treatment might modify this eventual disability somewhat. The age, occupation and habits of the patient might modify it more. There was the possibility that secondary changes might develop in the course of time and still further affect the function of the joint.

[Ed. Note.—We have observed marked interference with function after deforming fractures of the acetabulum, especially those in which the femoral head penetrates the acetabulum. We believe that every effort should be made to correct the deformity in the early stage. The method described by Putti of two way skeletal traction would appear to offer an effective remedy.]

Dislocations and Simple Fractures of the Elbow.—Geist and Henry [78] reviewed 150 consecutive cases of simple fractures and dislocations about the elbow joint. The ages of the patients varied from 4 months to 77 years; 54 per cent of the cases occurred before the age of 16, and 20 per cent occurred between 21 and 30.

Of the dislocations, the posterior variety was the most common, constituting 6 per cent of the injuries. Backward dislocation with fracture occurred in 3.4 per cent of the patients. Internal lateral dislocation was present in 1.4 per cent of the patients. In 2 per cent a dislocation of

77. Sever, James Warren: New England J. Med. **199**:16 (July 5) 1928.

78. Geist, E. S., and Henry, M. O.: Minnesota Med. **11**:509 (Aug.) 1928.

the head of the radius occurred. There were no cases of anterior or divergent dislocation.

The fractures were divided as follows: the lower end of the humerus, 61.4 per cent; the upper end of the radius, 10.7 per cent; the upper end of the ulna 8.6 per cent; explosion fracture (shattering of all bones), 6 per cent. The ulnar nerve was injured in several of the fractures of the internal condyle. The prognosis was considered serious in fractures of the head and neck of the radius, and it was often necessary to remove the radial head. The authors advised operative suture in all cases of fracture of the olecranon with displacement. They considered the prognosis bad in all patients with shattering fractures of the lower end of the humerus. They obtained better results by conservative treatment than by operative treatment in this type of fracture. They advocated immobilization of the elbow in a position of 75 degrees flexion with early active and passive motion.

Fractures of the Upper End of the Femur.—By experiments performed on the cadaver, Shaw [79] was able to refute the contentions of Stebbing based on clinical observations that intertrochanteric fractures of the femur were due to indirect violence and that direct violence on the trochanter caused a fracture of the acetabulum, rather than an intertrochanteric fracture. Shaw was able to produce intertrochanteric fractures by the application of direct violence to the trochanter and also by outward leverage on the shaft of the femur when the head and trochanter were fixed. Axial force applied to the femur (hammering on the lower end of the shaft) did not cause an intertrochanteric fracture. He was unable to produce a fracture of the acetabulum, although increasing powerful pressure on both trochanters caused fractures of the rami of the pubis and ischium.

Skeletal Traction in the Treatment of Fractures.—Groves [80] described his technic for applying skeletal traction in the treatment for fractures. He preferred transfixion pins to nails, ice tongs or Finochietto's stirrup. He transfixed the femur above, not through, the condyles to avoid the synovial sac of the knee joint and to obtain a pull from the dense bone of the shaft rather than from the cancellous bone. For fractures of the lower third of the femur and those involving the knee joint, he transfixed the crest of the tibia just below the tubercle. He employed traction force of from 20 to 60 pounds (9 to 27 Kg.), with counter traction obtained by raising the foot of the bed 12 inches (30.5 cm.) and passing padded perineal bands round each thigh and tying them to the upper posts of the bed. In treating fractures of the tibia and fibula, he transfixed the posterior process of the os calcis as far back as possible in

79. Shaw, J. J. M.: Brit. J. Surg. **16**:120 (July) 1928.
80. Groves, E. W. Hey: Brit. J. Surg. **16**:149 (July) 1928.

order to counteract the pull of the tendo achillis; in fractures through the upper third of the leg bones or in fractures of the ankle with separation of the tibia and fibula, however, he preferred to transfix the malleoli. He seldom used skeletal traction in the upper limb, although occasionally he found it necessary to transfix the olecranon, using a 10 pound (4.5 Kg.) weight, in severe fractures of the humerus just above or into the elbow joint.

Living Suture Grafts in the Repair of Fractures and Dislocations.—Allen [81] reported that he had employed strips of fascia lata for the suture of fractures of the patellae and olecranon in a series of patients who had been followed over a period of several years. The technic consisted in passing the strip through holes drilled in the fragments, crossing the ends on the anterior surface of the patella by passing one through the other and suturing the ends to the fascia or tendon above and below the fracture. The lateral tears in the aponeuroses were repaired with chromic gut. The advantages of the method were its strong mechanical fixation and the ability to stand the strain of motion begun at the end of one week. Splinting was not required. In the patients followed, there were no refractures and functional recovery was obtained at an earlier period than when the fragments were sutured by the usual methods.

Allen also successfully employed fascia lata for securing dislocations of the sternal end of the clavicle and for fixing the radial head in a patient with recurrent dislocation of this bone.

[Ed. Note.—Allen developed his method of fascial repair of fractures of the patella and olecranon on the Fracture Service of the Massachusetts General Hospital, and the method has appeared to have so much advantage that it has been generally adopted by the other members of the staff.]

DISLOCATIONS

Fracture Dislocation of the Shoulder.—Gerard-Marchant [82] made a study of fracture dislocations of the shoulder, including only those cases in which there existed a complete interruption in the continuity of the bone between the head and the upper part of the shaft. His conclusions were based on an analysis of 353 cases.

He found that the anteromedial type of dislocation was almost the rule, and that the fracture involved the surgical neck in 51 and the anatomic neck in 38.5 per cent of the cases. He was unable to note any difference in the type of the articular lesion accompanying the two varieties of fracture.

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81. Allen, Arthur: Living Suture Grafts in Repair of Fractures, Arch. Surg. **16**:1007 (May) 1928.

82. Gerard-Marchant, M. P.: J. de chir. **31**:695 (May) 1928.

Reviewing the different methods of treatment and their results, he called attention to the fact that reduction might be accomplished in a certain number of patients by closed methods irrespective of whether the fracture involved the surgical or the anatomic necks. Complete functional recovery was obtained in about one half of the patients in whom reduction was accomplished by this means. Of the open methods of treatment, resection—that is, the excision of a larger or smaller entirely detached fragment—when performed soon after the injury, yielded on the whole imperfect results. The results of late resection were better. Replacement of the dislocated fragment by open operation performed soon after the injury gave results superior to those obtained by other methods. Late reductions gave varying results.

Actually, the methods of choice were, first, closed reduction and, second, open replacement. In fractures of the anatomic neck, these two methods appeared to be of about equal value; in fractures of the surgical neck, open replacement seemed to be the better method. Against closed reduction were the dangers of nerve injury or vascular rupture but, on the other hand, opening the articulation by surgical incision was not without danger. The open method ought not to have absolute priority over the closed method except in case of neurovascular lesions. In fractures of the surgical neck, one ought never to resort to resection. In fractures of the anatomic neck, resection might be indicated under certain conditions. In fractures involving the upper end of the humeral shaft, replacement could be the only aim. In the comminuted fractures in which the head escaped from the capsule in fragments, it was necessary to be sparing in the resection of the fragments.

Discussing the treatment for fracture dislocations of the shoulder, Taylor [83] described a method of treatment which he had successfully employed in several cases. Instead of manipulating or performing an open operation, he applied traction with the arm in abduction and the patient recumbent. He reported one case in which reduction was effected in four days. The fracture was reduced by increasing the degree of abduction of the arm to 120 degrees. Union was sufficiently solid in three weeks to allow immobilization in a plaster casing.

[ED. NOTE.—Of the various bony injuries, we know of none in which treatment is more difficult or prognosis more uncertain than fracture dislocations of the shoulder. When the fracture involves only the greater tuberosity the problem is relatively simple, and reduction can generally be accomplished by the closed method. Gérard-Marchant's conclusions as to the superiority of open replacement over resection are in accord with our own observations, although the operation is

83. Taylor, R. T.: Fracture Dislocations of Shoulder, Arch. Surg. **17**:475 (Sept.) 1928.

attended by much greater difficulty. Even then, complete functional recovery cannot be expected. We shall be interested to try the method described by Taylor. In obese patients, or when for any reason open operation is contraindicated, we think that there is something to be said for the old method of waiting for three to four weeks to allow the fracture to unite before attempting closed reduction.]

Dislocation of the Carpal Semilunar Bone.—Ettorre [84] preferred the term traumatic enucleation of the semilunar bone to dislocation, pointing out that the cases fell into two classes, one which he called a perilunar luxation in which the displacement was between the semilunar and the os magnum, the former maintaining its normal relation to the radius, and a second class in which the semilunar was dislocated anteriorly in relation to both the os magnum and the radius. He considered the second class as the true enucleation. He believed the type of luxation to be determined by the shape of the semilunar bone which had a variety of forms, and also by the strength of the ligaments as well as by the direction and force of the trauma. The author advised closed reduction in early cases in which the rotation of the bone was not complete. He warned of the possibility of injury to the median nerve in the manipulations.

AMPUTATIONS

Formation of the Gritti-Stokes Stump.—In thirty Gritti-Stokes amputations, Oehlecker [85] stated that he had fixed the patella to the femur by wedging it into an especially prepared mortise. He removed the cartilage from the under surface of the patella and shaped it into a square plug by means of a jig-saw. He then fitted this plug into a similarly shaped depression in the end of the femur. This method yielded a firm, painless end weight-bearing stump.

RESEARCH

Investigation of Adolescent Kyphosis.—Having been interested for several years in the subject of adolescent kyphosis and having published previous articles on the subject, Mau [86] undertook to reproduce the condition experimentally and reported the results. He sewed the end of the shortened tail of young rats beneath the skin, making a marked curve. The animals were killed and examined after different intervals. He found that definite changes developed in the epiphyseal cartilages; on the concave side, there was irregular proliferation and limitation of growth of the endochondral bone. The bony framework of the body underwent change and showed new formation of bony trabeculae, with

84. Ettorre, E.: Chir. d. org. di movimento **12**:153 (March) 1928.

85. Oehlecker, F.: Zentralbl. f. Chir. **55**:2250 (Sept. 8) 1928.

86. Mau, C.: Ztschr. f. orthop. Chir. **51**:106, 1929.

the development of marginal proliferations such as are seen in arthritis; the body itself became wedge-shaped, with the apex toward the concave side. As a result of pressure atrophy, the margin of the epiphysis bordering on the concave side disappeared completely. Parts of the epiphyses showed necrotic changes. The author considered that the whole process was one of functional adaptation to a habitual curve and that the mechanism of these changes, which so closely resembled those seen in roentgenograms of pateints with adolescent kyphosis, was one of circulatory interference.

Experimental Study of Muscle Atrophy.—Lippmann and Selig [87] produced muscle atrophy in rabbits by various means: immobilization of an extremity, section of a nerve, tenotomy and the production of an irritative arthritis. They found that atrophy due to immobilization alone was relatively small in degree and slow in onset as compared to that which followed arthritis, nerve section or tenotomy. They inferred that although arthrogenic atrophy had to be considered as an atrophy of disuse, it was not the result of immobilization but was caused by a reflex mechanism.

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87. Lippmann, Robert; and Selig, Seth.: Surg. Gynec. Obst. **47**:512 (Oct.) 1928.

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